STATE OF OHIO
MICHAEL V. DiSALLE, Governor
DEPARTMENT OF NATURAL RESOURCES
HERBERT B. EAGON, Director
DIVISION OF GEOLOGICAL SURVEY
RALPH J. BERNHAGEN, Chief

BULLETIN 60

GEOLOGY OF FAIRFIELD COUNTY

BY

EDWARD W. WOLFE
JANE L. FORSYTH
GEORGE D. DOVE

COLUMBUS
1962

Geology of Fairfield County

Ohio Division of Geological Survey Bulletin 60

ERRATA

Title page - The credit should read "Chapter on Ground-Water Resources Prepared in Cooperation with the U. S. Geological Survey and the Division of Water, Ohio Department of Natural Resources."

Page ii - last sentence should read "The chapter by George D. Dove is the result of a study carried out by the Columbus office of the U. S. Geological Survey, Ground Water Branch, in cooperation with the Division of Water, Ohio Department of Natural Resources. It is published with the permission of the Director, U. S. Geological Survey, and the Chief, Division of Water, Ohio Department of Natural Resources.

Page 123 - figure 40 - the vertical drafted lines at the points of the arrows should be disregarded; on the photograph itself the faint line on the ground between the arrows marks the boundary between end moraine and ground moraine.

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PREFACE

This bulletin represents the combined work of three authors whose responsibility is divided as follows: Edward W. Wolfe for the geologic map (pl. 1) and chapters 1, 2, 3, 4, 5, 6, and 9; Jane L. Forsyth for the glacial map (pl. 2), chapter 7, and small sections in chapters 2, 5, 6, and 9; and George D. Dove for the ground-water resources map (pl. 3) and chapter 8. The work of Edward W. Wolfe, with some changes, embodies a dissertation presented in partial fulfillment of the requirements for the degree Doctor of Philosophy at The Ohio State University, Department of Geology. The part of the report by Wolfe was prepared under the direction of Aurèle LaRocque, Department of Geology, The Ohio State University, who edited the manuscript for publication. Sections of the report prepared by Jane L. Forsyth are the result of an investigation undertaken by her for the Ohio Division of Geological Survey to complete the geological study of Fairfield County. The chapter by George D. Dove is the result of a study carried out by the Columbus office of the U. S. Geological Survey, Ground Water Branch, and is published with the permission of the Director, U. S. Geological Survey.

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Chapter 1

INTRODUCTION

LOCATION AND EXTENT OF AREA

Fairfield County is located in south-central Ohio and is bounded by Franklin, Licking, Perry, Hocking, and Pickaway Counties (fig. 1). The area of the county is approximately 500 square miles, and it includes portions of the following U. S. Geological Survey 15-minute quadrangles: Circleville, East Columbus, Lancaster, Logan, Thornville, and Thurston (fig. 1). These quadrangles lie between 39° 30' and 40° 00' north latitude and 82° 15' and 83° 00' west longitude.

Lancaster, the county seat, is the largest municipality in Fairfield County. It is located in the Hocking Valley at the intersection of Greenfield, Pleasant, Berne, and Hocking Townships. Smaller municipalities are Pickerington, Basil, Baltimore, Millersport, Thurston, Pleasantville, Lithopolis, Carroll, and Rushville in the northern part of the county, and Bremen, Sugargrove, and Amanda in the southern part of the county. The southwestern end of Buckeye Lake, a resort area, lies in northeastern Walnut Township.

Fairfield County is served by two federal highways, U. S. Routes 22 and 33. In addition, there are a number of State highways and many county and township roads. With only a relatively small amount of walking, any point in Fairfield County can be reached readily from a road. The county is also served by three railroads, the Chesapeake and Ohio, the Pennsylvania, and the New York Central.

PURPOSE AND SCOPE OF INVESTIGATION

The main purpose of this investigation is the mapping and description of the strata that immediately underlie the bedrock surface in Fairfield County, the interpretation of their stratigraphic relationships, and the mapping and description of the glacial deposits which overlie them in most places. Consideration of structural geology, erosional history, and geologic history, as well as the economic geology of the area, is treated in less detail than is the stratigraphy. Most parts of this report, that is, those which are concerned with the nature and significance of the bedrock and of its erosional history, have been prepared by Edward W. Wolfe. The geology of the glacial deposits, chapter 7, is described and interpreted by Jane L. Forsyth, whose report incorporates earlier work by James F. Conley (1956). Ground-water resources of Fairfield County, chapter 8, are discussed by George D. Dove of the U. S. Geological Survey.

Figure 1. - Index map showing location of Fairfield County, Ohio. The county is covered by parts of the following U. S. Geological Survey quadrangles: (1) East Columbus, (2) Thurston, (3) Thornville, (4) Circleville, (5) Lancaster, and (6) Logan.

METHOD OF INVESTIGATION

The fieldwork for this report consisted largely of noting the location, detailed lithologic character, and elevation of rock outcrops and geologic contacts along roads and stream valleys. Locations of outcrops and exposed geologic contacts were plotted on U. S. Geological Survey topographic maps on a scale of 1:62,500, which were used as base maps. Lithologic descriptions include only those features which are readily seen in the field with the aid of an ordinary hand lens. Colors were determined by comparison with the Rock-Color Chart prepared by the Rock-Color Chart Committee and distributed by the Geological Society of America. They are referred to in this report by the name and numerical classification of the chart, as for example, grayish red (10 R 4/2). Elevations were determined by various methods, including hand leveling from a point of known altitude, taking readings with an aneroid barometer and Paulin altimeter, and estimation from the topographic map. The last named method, which is probably the least accurate, ordinarily is impractical except along roads, because of the difficulty of determining locations precisely in the absence of prominent landmarks. Furthermore, the accuracy of the topographic maps is questionable in rugged or wooded areas.

Detailed stratigraphic sections were measured wherever a suitable exposed sequence of strata was found. These stratigraphic sections are on file with the Ohio Division of Geological Survey and are referred to in this bulletin by their Survey (O. G. S.) file numbers, as for example, stratigraphic section O. G. S. 15546. The more important stratigraphic sections in Fairfield County are given in the appendix of this report. Ordinarily, thicknesses of beds were determined by use of a hand level and Jacob's staff, but in a few instances, where especially thick units were involved or where visibility was seriously impeded by vegetation, thicknesses were determined by use of a Paulin altimeter. Elevations at the base of stratigraphic sections were determined by hand leveling from a point of known elevation or by taking readings with a Paulin altimeter. Ordinarily the gentle eastward dip of the strata does not cause appreciable error in thicknesses, but in stratigraphic sections covering long horizontal distances at right angles to the strike, true thicknesses are not measured.

Because of poor exposures, it is impossible to walk out a geologic contact and plot its distribution in the field. Consequently, the geologic contacts shown on the map (pl. 1) were drawn by plotting points of known elevation on the map and connecting them.

In much of the area the bedrock surface is heavily covered by glacial drift. The approximate configuration of the bedrock surface was determined by means of outcrop data and all available oil and water well data. Geologic contacts were plotted on the buried portion of the bedrock surface by projection from outcrops and by utilization of the available data from well records and cuttings.

PREVIOUS INVESTIGATIONS

The earliest known published record of geological observation in Fairfield County is that of Hildreth (1834). He wrote a brief description of the Rush Creek gorge and noted the occurrence of sandstone at Mt. Pleasant. He described the glacial outwash immediately west of the Hocking River (1834, p. 238) as "a compound of primitive, transition, and secondary materials, the ruins of former rock formations."

E. B. Andrews was the first to attempt a systematic description of the geology of Fairfield County. In 1870 he published an account of the Waverly strata in the Hocking Valley, and in 1874 he briefly described the drainage and glacial deposits, as well as the strata exposed at Lithopolis, in the Hocking Valley, and in the Rush Creek gorge.

No further important contributions to the knowledge of the exposed bedrock were made until the early part of this century. In the meantime, however, the Sugargrove and Thurston gas pools were developed, and a number of papers (Orton, 1888, 1888a, 1890; Bownocker, 1903, 1903a) describing their development and summarizing the knowledge of their geology ensued. The Bremen oil pool was opened in 1907, and in 1910 Bownocker published a comprehensive report on the development and geology of the pool. An article on the "Clinton" sand, with special emphasis on its occurrence at Bremen, was published by Bownocker the following year.

In 1902 the U. S. Geological Survey began an investigation of the geology of the Columbus quadrangle, which includes a portion of Bloom and Violet Townships of Fairfield County. Four important reports resulted. Prosser and Cumings (1904), who mapped the geology of the southern half of the Columbus quadrangle, produced a paper treating in detail the Bedford, Berea, Sunbury, and Cuyahoga formations of northwestern Fairfield County and the immediately adjacent area. A paper on the same strata, but with particular emphasis on the Bedford-Berea disconformity, was published by Prosser (1912). The work culminated in two major reports on the geology of the Columbus quadrangle. The first was published as Bulletin 14 of the Geological Survey of Ohio (Stauffer, Bownocker, and Hubbard, 1911), and the second was published by the U. S. Geological Survey as the Columbus folio (Hubbard and others, 1915).

J. E. Hyde, a native of Rushville, published a comprehensive report on the geology of Fairfield County in 1912. The report included descriptions of the bedrock, glacial deposits, drainage changes, and geologic history. Two later publications, one in 1915 and the second issued posthumously in 1953, deal with the Waverly formations of central and southern Ohio, but they include detailed discussions of the geology of Fairfield County. Undoubtedly Hyde contributed more to the understanding of the Ohio Waverly than any other student of the Waverly. His work provided an amazingly accurate frame of reference which has been expanded but little modified by his successors.

A number of more recent students have continued the study of the Ohio Waverly. Important studies which include parts of the geology of Fairfield County within the framework of a larger study have been made by Holden (1942), Pepper and others (1954), and Swick (1956).

No detailed maps of the bedrock geology of Fairfield County have been published. However, Hyde mapped the Mississippian formations of much of the county, and Schroyer mapped the Mississippian-Pennsylvanian contact in the early part of this century (unpublished data in the files of the Ohio Division of Geological Survey).

Study of the glacial geology and the drainage history of Fairfield County has been carried on since the latter part of the nineteenth century. Among the important contributors have been Andrews (1874), Wright (1882), Chamberlin (1883), Tight (1897), Leverett (1902), Hyde (1904, 1912), Detmers (1912), Lamborn (1932), Stout and Lamb (1938), White (1939), Reutinger (1941), Stout, Ver Steeg, and Lamb (1943), Schuster (1952), Kempton (1956), Conley (1956), Kempton and Goldthwait (1959), and Dove (1960). Conley's (1956) description of the contributions of some of these early writers is given at the beginning of the discussion of the glacial deposits of Fairfield County, in chapter 7 of the present report.

ACKNOWLEDGMENTS

The authors are indebted to a number of persons who aided in the preparation of this report. Edward W. Wolfe expresses particular thanks to Dr. Aurèle LaRocque of the Department of Geology, The Ohio State University, who directed the investigation of the bedrock geology and guided him throughout the preparation of his portion of the report. Many others gave freely of their time in discussing with Wolfe the geology of Fairfield County. Among these, special thanks are due Dr. Jane L. Forsyth of the Ohio Division of Geological Survey, Dr. George J. Franklin of the Department of Geology, The Ohio State University, and writer's colleagues in the Department of Geology at the College of Wooster. Wolfe also wishes to thank several members of the Division of Geological Survey, Ohio Department of Natural Resources, including Miss Pauline Smyth, Mr. Karl V. Hoover, and Mr. Harold J. Flint, for their valuable assistance. Most helpful, too, was the assistance of Mr. Jon S. Galehouse during the summer of 1960.

Jane L. Forsyth wishes to express special appreciation to James F. Conley of the North Carolina Geological Survey for his thesis work on the glacial geology of Fairfield County, which provided much of the information upon which chapter 7 of the present report is based. Dr. Richard P. Goldthwait of the Department of Geology, The Ohio State University, who directed Conley's work, has also been of great help in the preparation of the present study; this help is gratefully acknowledged. In addition, thanks are also due to Dr. Nicholas Holowaychuk of the Department of Agronomy, The Ohio State University, and to Mr. James H. Petro and Mr. T. R. Smith of the Division of Lands and Soil, Ohio Department of Natural Resources, for aid in determining the nature and classification of soils. Most of the information about the outwash terraces of the Hocking Valley was made available through personal discussions with, and publications by, John P. Kempton, now with the Illinois Geological Survey.

The field work on the bedrock geology was sponsored and financed by the Division of Geological Survey, Ohio Department of Natural Resources. Additional financial aid, in the form of a William H. Wilson award was granted to Wolfe by the College of Wooster. Fieldwork on the glacial geology was financed by the Divisions of Water and Geological Survey, Ohio Department of Natural Resources, in their program of mapping locations of water wells in Fairfield County during the summer of 1959. Study of the ground-water resources of the county was financed and carried out by the U. S. Geological Survey, Ground Water Branch, and is published with the permission of the Director, U. S. Geological Survey.

Chapter 2

PHYSIOGRAPHIC SETTING

DRAINAGE

All surface waters of Fairfield County (fig. 2) eventually drain into the Ohio River via the Scioto, Hocking, or Muskingum Rivers. A large area, including most of the central and southeastern portions of the county is drained by the Hocking River and its major tributaries, Rush Creek, Little Rush Creek, and Clear Creek. In a small area in northern Walnut and northeastern Liberty Townships, the streams drain into Buckeye Lake, which empties north into South Fork of the Licking River, a part of the Muskingum drainage.

The remainder of the county, including much of the western tier of townships and most of the area in the northern tier of townships is drained by tributaries of the Scioto River. Scippo Creek drains western Clear Creek Township. The central and southeastern portions of the township, as well as a very small area along the southern border of Madison Township, are drained by Salt Creek and its tributaries.

Walnut Creek drains western Amanda Township, western and northeastern Bloom Township, and the northern parts of Greenfield and Pleasant Townships. It drains all of the northern tier of townships except for a small area in southeastern Walnut Township, which is drained by Rush Creek of the Hocking drainage; the Buckeye Lake area in the northeastern corner of the county, which lies in the Muskingum drainage; and a small area in northwestern Violet Township, which is drained by Blacklick Creek, a tributary of Big Walnut Creek, which empties into the Scioto River.

RELIEF

The highest points in Fairfield County are in central and west-central Hocking Township. Here several hills in the vicinity of Delmount rise to elevations of from 1240 to 1260 feet above sea level. The lowest point in the county occurs where Walnut Creek crosses the county line in southwestern Violet Township. The elevation at this point is from 740 to 750 feet above sea level. The maximum relief in the area, therefore, is approximately 500 feet.

The greatest local relief occurs in the south-central part of the county, where in eastern Madison Township a few hilltops rise more than 400 feet above the floor of Clear Creek. A difference in elevation of more than 400 feet occurs in a horizontal interval of about half a mile in section 24, Madison Township.

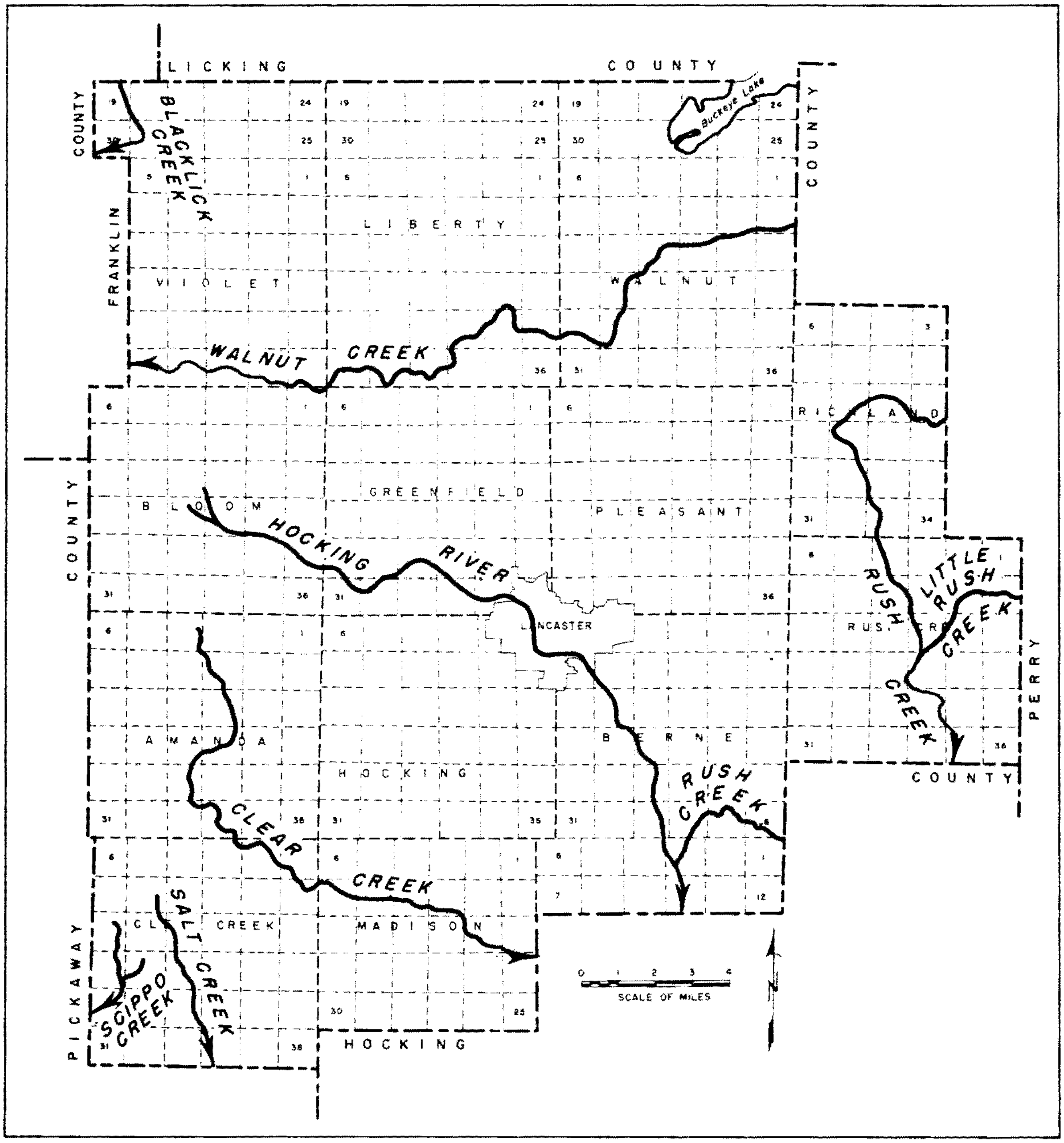


Figure 2. - Major lines of drainage in Fairfield County.

PHYSIOGRAPHIC SUBDIVISIONS

GENERAL STATEMENT

Fairfield County includes a portion of the Till Plains section of the Central Lowlands province (fig. 3) and a portion of the Unglaciated Allegheny Plateau section of the Appalachian Plateau province (Fenneman, 1938). A third physiographic region, transitional between the Till Plains and the Unglaciated Allegheny Plateau, may be distinguished. This region, the glaciated portion of the plateau, is too small an area to have been set aside by Fenneman, whose section called the Glaciated Allegheny Plateau (1938, pl. II) lies far to the north of Fairfield County.

UNGLACIATED ALLEGHENY PLATEAU

The Unglaciated Allegheny Plateau as it appears in Fairfield County is a well-drained, maturely dissected region characterized by narrow valleys and steep hillsides. The largest valleys, however, are wide and flat bottomed because of partial filling by glacial outwash. Except for an area in Rush Creek Township, where the basal sandstones of the Pottsville group form a local cuesta, the divides are commonly narrow. The local relief in most of the area ranges from about 100 to 300 feet. The boundary between the Unglaciated Allegheny Plateau and the Glaciated Allegheny Plateau does not lie at the glacial boundary, but at the place where the topography begins to be controlled by the blanket of glacial deposit. As a result, much of the Unglaciated Allegheny Plateau has actually been glaciated, but the capping drift is so thin that it produces little modification of the topography of the underlying bedrock surface.

The writer recognizes typical Unglaciated Allegheny Plateau topography in Rush Creek Township, in Berne Township south of the buried valley which trends east from Lancaster, in eastern Madison Township, in southeastern Hocking Township, and in a small area on Chestnut Ridge in north-central Bloom Township. The rugged area immediately north of Lancaster also forms a short spur of the Unglaciated Plateau.

The western part of the Unglaciated Allegheny Plateau is underlain by resistant, ledge-forming Black Hand sandstone. In the eastern part of the county the surface of the Unglaciated Plateau is formed by the resistant basal sandstones of the Pottsville group.

TILL PLAINS

The Till Plains section occupies the northern tier of townships. It is also present west of the Appalachian Plateau in Amanda and Bloom Townships, as well as in the vicinity of the deep buried valley which lies between the two northern spurs of the Plateau in Greenfield and northern Hocking Townships. It includes those portions of the county in which the configuration of the bedrock surface has been almost totally obscured by drift. The land surface is typically youthful, gen-

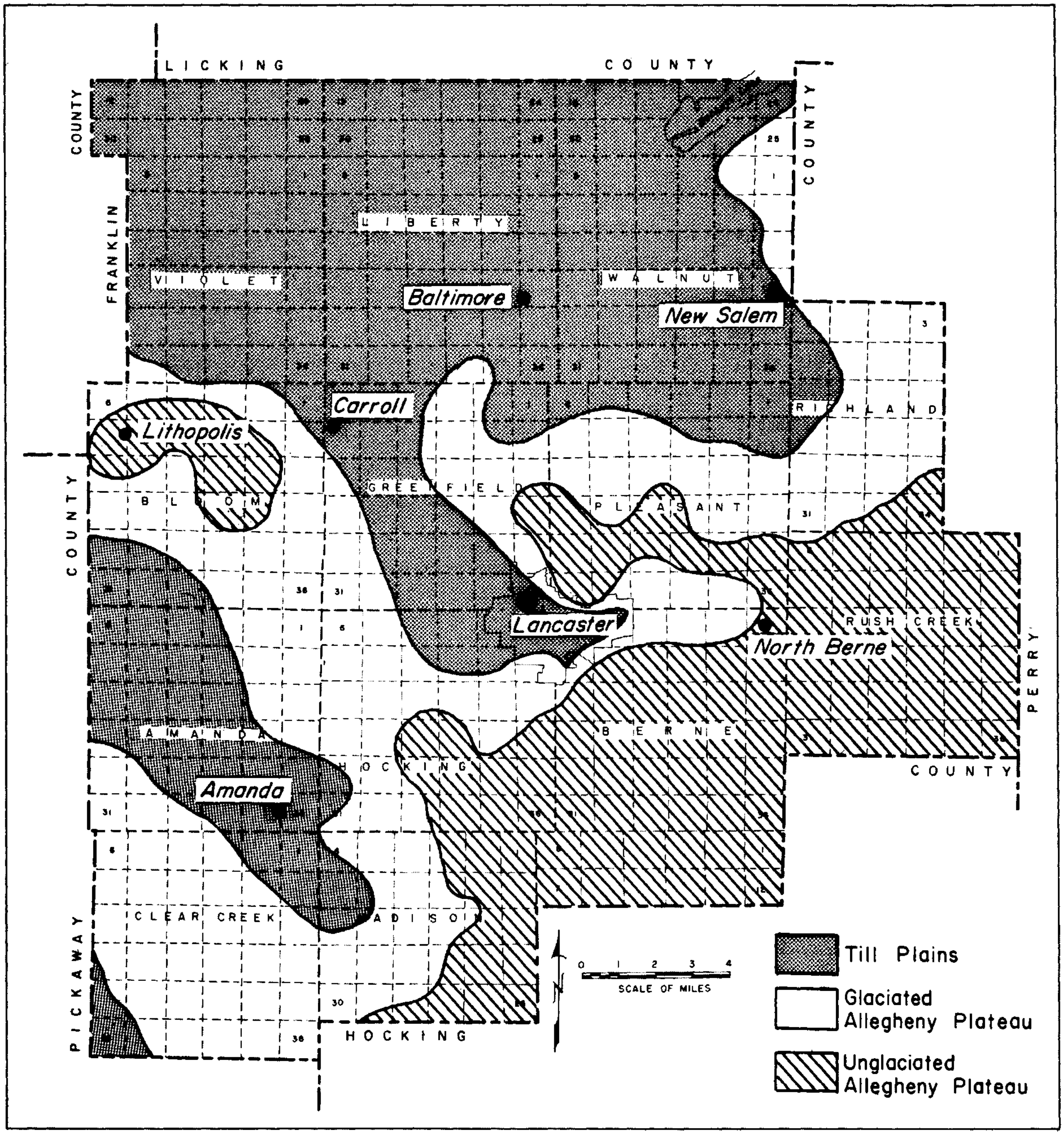


Figure 3. - Physiographic subdivisions of Fairfield County.

tly undulating, and in general, poorly drained. The boundary between the Till Plains and Plateau sections is marked in Fairfield County by an escarpment which overlooks the Till Plains. In some areas the escarpment is subdued rather than steep.

The Till Plains section lies on a land surface which stood well below the general level of the Appalachian Plateau and was traversed by wide, deep valleys in preglacial times. In Fairfield County, this lower, buried land surface overlies the easily eroded strata of the Raccoon member and the soft shales beneath the Raccoon.

GLACIATED ALLEGHENY PLATEAU

In some localities, the Till Plains and Unglaciated Allegheny Plateau sections are separated by a zone which displays characteristics of both the Till Plains and the Unglaciated Plateau. Such areas occur in the western part of the county in Bloom, Amanda, Clear Creek, western Hocking, and western Madison Townships, in the central and eastern parts of the county from east-central Greenfield Township to Richland Township, and in the northeastern part of the county in the area east and southeast of Buckeye Lake. These areas, which are the sites of bedrock highs that formed divides on the preglacial land surface, lie within the Wisconsin glacial boundary. Scattered outcrops indicate the proximity of the bedrock surface to the modern land surface. Topographically, the Glaciated Allegheny Plateau in Fairfield County is considerably less rugged than the adjacent Unglaciated Plateau. The drainage is not as well established as that of the Unglaciated Plateau, and poorly dissected uplands are common. Although the Glaciated Plateau has much in common with the Till Plains, it differs significantly because of the pronounced effect of the bedrock highs on the present topography.

Chapter 3

STRATIGRAPHY

GENERAL STATEMENT

The rocks that crop out in Fairfield County range in age from late Devonian or early Mississippian to early Pennsylvanian. Because of the gentle eastward regional dip, the oldest beds crop out only near the western border of the county, and the strata are progressively younger to the east. The stratigraphic section is composed almost entirely of clastic rocks consisting mainly of shales, mudstones, siltstones, sandstones, and conglomerates. In ascending order it includes the Ohio shale of late Devonian and possibly of early Mississippian age; the Bedford, Berea, and Sunbury formations of Kinderhook age; the Cuyahoga formation of Kinderhook and Osage ages; the Logan formation of Osage age; the Maxville limestone of Meramec age; and the Pottsville group of early Pennsylvanian age, which lies unconformably on the Mississippian rocks. Resting unconformably on the Paleozoic rocks of Fairfield County are unconsolidated deposits belonging to the Quaternary system. The stratigraphic relations and structure of the exposed bedrock strata are shown in a generalized cross section in figure 4.

DEVONIAN SYSTEM

OHIO SHALE

Definition

The Ohio shale was named by Andrews (1870, p. 62) for exposures of black bituminous shale overlying the Delaware limestone near Columbus, Ohio. Winchell (1874, p. 243, 287), on the basis of exposures along the Olentangy River in Delaware County, separated the lower 30 feet, consisting of bluish or greenish shale with less bituminous matter, and called it the Olentangy shale. The Olentangy shale has for many years been regarded as a distinct formation overlain by the Ohio shale or the Huron shale in northern Ohio. The Ohio shale is, therefore, restricted to those rocks overlying the Olentangy shale of Devonian age and underlying the Bedford shale of Mississippian age (Wilmarth, 1938, p. 1534, 1543).

Distribution

The Ohio shale was observed in only one outcrop in Fairfield County, under water in a small ravine in the NW$\frac{1}{4}$ of section 6, Bloom Township (O. G. S. 14606). In Madison Township, Franklin County, near the Fairfield County border, it is exposed along Big Run in the SE$\frac{1}{4}$ of section 12 (O. G. S. 14572, 14573), in the stream bed in the SE$\frac{1}{4}$ of section 1 (O. G. S. 10591), and in the SW$\frac{1}{4}$ of section 31 where Walnut Creek intersects Ohio Route 674.

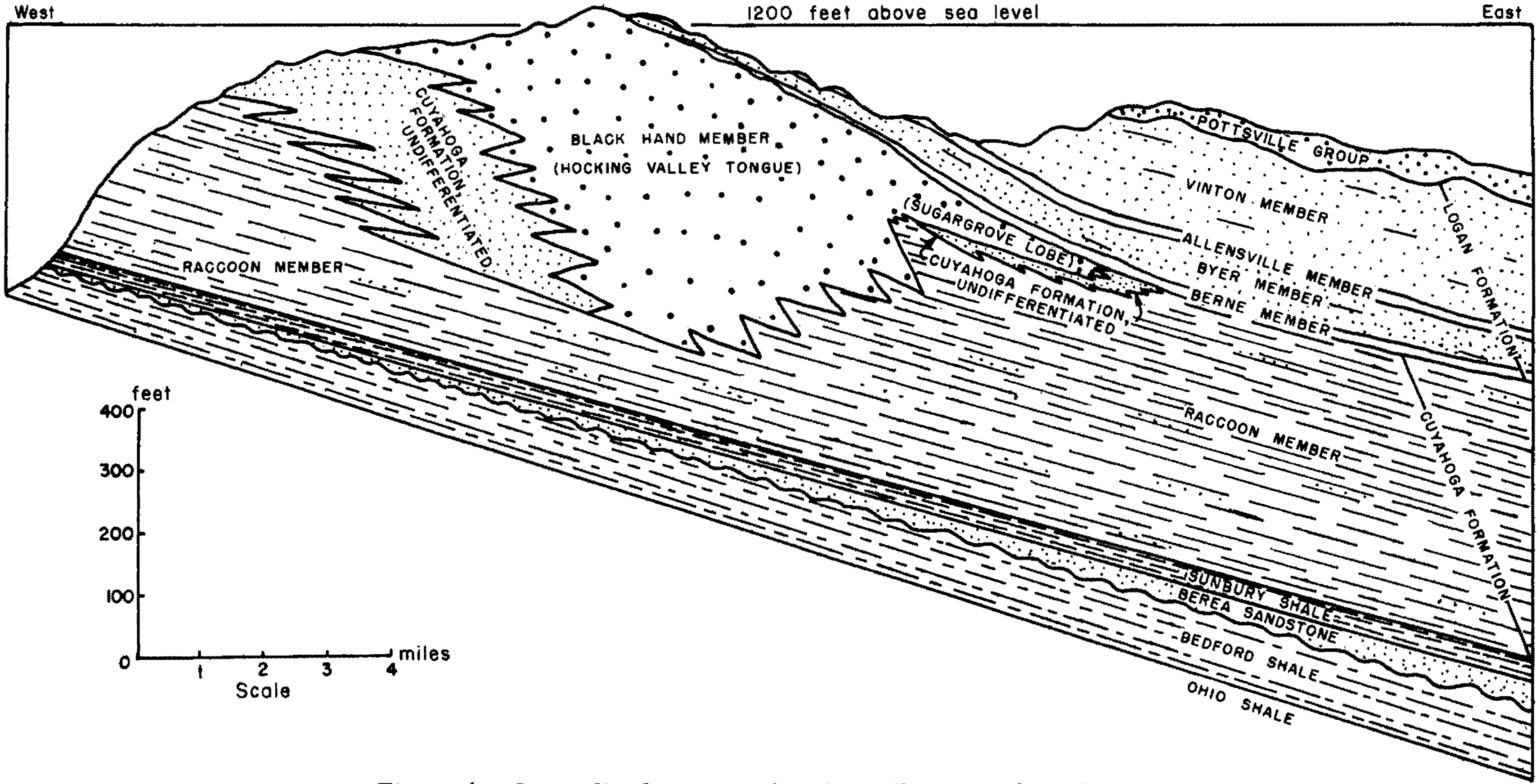


Figure 4. - Generalized cross section in southern Fairfield County.

Oil and gas well records indicate that the Ohio shale is present everywhere in the subsurface of Fairfield County. Because of the regional dip, the upper surface descends from at least 775 feet above sea level in the northwest corner of Bloom Township to near sea level in the easternmost portion of the county. The Ohio shale forms the floors of the deeper buried valleys in western Amanda and southwestern Bloom Townships, and in northwestern Greenfield, southwestern Liberty, northern Bloom, and Violet Townships.

Lithologic Character

In western Fairfield County and in the nearby Franklin County outcrops the Ohio shale is a black, very slightly silty, fissile shale. It is fairly hard and brittle and in places it is iron stained on weathered surfaces.

Thickness

Only a very small portion of the upper part of the Ohio shale is exposed in and near Fairfield County. The approximate thickness may, however, be determined from those oil well records in which the drillers have distinguished the dark Ohio shale from the red and gray shales of the Bedford above and the gray Olentangy shale which separates it from the Delaware limestone below.

A pronounced eastward thickening of the Ohio shale from 475 feet or less to 800 feet or more can be recognized. Lamborn (unpublished data, Ohio Division of Geological Survey) described cuttings from a well (O. G. S. sample No. 438) located in section 30, Amanda Township, near the western border of Fairfield County. According to his description, a thickness of 475 feet is determined for the Ohio shale at this locality. A driller's record from a well in northwestern Fairfield County (Pickerington Creamery, well No. 3) suggests a thickness of 503 feet. The remainder of the wells in which the Ohio shale is recognized in drillers' logs are clustered in the eastern half of the county, in Walnut, Pleasant, Richland, and Rush Creek Townships. Here the thickness ranges from 618 to 801 feet, with a general tendency to increasing thickness eastward. The driller's log of a well (Prudential Insurance Company, well No. 1; drilled by the Wiser Oil Co.) in section 24, Pleasant Township, shows only 594 feet of the Ohio shale. However, the thickness of the overlying Bedford, reported as 108 feet, seems excessive, and the exact location of the well is unknown. Its slightly anomalous record is therefore disregarded.

Stratigraphic Relations

In central Ohio the Ohio shale overlies the Olentangy shale and is overlain by the Bedford shale. The basal contact lies far below drainage in Fairfield County and the upper contact is covered in the single Fairfield County outcrop and in the nearby Franklin County outcrops. The upper contact is discussed further in connection with the stratigraphic relations of the Bedford shale (p. 17-18).

The Ohio shale forms a portion of a larger body of black shale which includes in approximately the same stratigraphic interval parts of the Chattanooga shale of eastern Kentucky and Tennessee and the New Albany shale of western Kentucky and Indiana. In northern Ohio the Ohio shale has been subdivided into, in ascending order, the black Huron shale (Newberry, 1870, p. 18), Chagrin shale

(Prosser, 1903, p. 521) consisting of gray shale and siltstone, and the black Cleveland shale (Newberry, 1870, p. 19, 21). Cushing (1912, p. 583) separated 15 to 60 feet of soft blackish shale with thin bands of blue shale from the base of the Cleveland shale, calling it the Olmsted shale member of the Cleveland shale. Cooper and others (1942), following Prosser (1912a, p. 515), considered the Huron shale to be the western black shale facies of the Chagrin. Chadwick (1925) and Cushing (1931) believed that the Olmsted shale member of the Cleveland shale rests unconformably on the Huron and Chagrin shales and overlaps them toward the east. Pepper and others (1954, p. 14-17) proposed to treat the Cleveland and Huron as members of the Ohio shale rather than as separate formations because at Norwalk, Huron County, they are inseparable, except paleontologically. In Lorain County the Huron and Cleveland members are separated by a tongue of Chagrin shale which interfingers with the Ohio shale. The Olmsted was interpreted by Pepper and others as representing only "minor interfingering of the black shales of the Ohio and the gray shales of the Chagrin prior to the main eastward transgression of the sea which deposited the main mass of the Cleveland member" (Pepper and others, 1954, p. 16).

Age

The age of the Ohio shale and the position of the Devonian-Mississippian boundary in Ohio have long been debated. The Huron, Chagrin, and Cleveland shales were considered Devonian until 1912 when Ulrich assigned them to the Mississippian system and initiated the controversy which is not yet resolved. Since 1912 many geologists have studied the Devonian-Mississippian boundary problem, and the boundary has been variously placed between the base of the Huron shale and its equivalents and the base of the Berea sandstone. The long history of the boundary problem has been summarized by Schuchert (1943, p. 564-570).

Cooper and others (1942, p. 1753) suggested that the Cleveland shale is of probable Devonian age. Weller and others (1948), following Campbell (1946), correlated the Ohio shale, as well as the overlying Bedford, Berea, and Sunbury formations, with the New Albany shale of Indiana. The lower part of the New Albany shale, which was correlated with the lower part of the Ohio shale, is of certain Devonian age. The Cleveland shale (upper part of the Ohio shale of central Ohio) and the Bedford, Berea, and Sunbury formations were correlated with the upper part of the New Albany shale. An early Mississippian (Kinderhook) age was indicated for the upper part of the New Albany shale on the basis of flora, brachiopods, and conodont assemblages (Campbell, 1946, p. 853). The Devonian-Mississippian boundary was thought to be below the upper part of the New Albany shale of Indiana and within the Ohio shale of central Ohio.

Hass (1947, p. 138), on the basis of conodont assemblages in Ohio, correlated the lower part of the Ohio shale with the lower part of the New Albany shale and regarded these strata as late Devonian in age. He considered the Berea and Sunbury equivalent to the upper part of the New Albany shale and assigned them to the Mississippian system. The upper part of the Ohio shale and the Bedford formation were thought to be intermediate in age between the upper and lower parts of the New Albany shale, and he classified them as Devonian or Mississippian.

Pepper and others concluded, on the basis of their paleogeographic interpretation, as well as on evidence supplied by vertebrate fossils, that "the Bedford shale makes the most logical choice of formations for the basal unit of the Mississippian of Ohio" (Pepper and others 1954, p. 12). Therefore they assigned the Ohio shale to the Devonian system.

Hass (1956, p. 23) revised his earlier correlation. He considered the Sanderson formation of the upper part of the New Albany shale to be of late Devonian age, and correlative with the upper part of the Ohio shale.

Following long established custom, and for the sake of convenience, the Ohio shale is classified on the geologic map (pl. 1) as Devonian. The writer prefers for the time being, however, to regard the upper part of the formation as Devonian or Mississippian in age.

MISSISSIPPIAN SYSTEM

GENERAL STATEMENT

The Mississippian system in Fairfield County is represented, in ascending order, by the Bedford, Berea, and Sunbury formations of Kinderhook age, the Cuyahoga formation of Kinderhook and Osage ages, the Logan formation of Osage age, and the Maxville limestone of Meramec age. The strata occurring between the Ohio shale and the base of the Pottsville group were included by Briggs (1838, p. 79) in his Waverly sandstone series, named for exposures at Waverly, Pike County. Wilmarth (1938, p. 2288) stated that the term "Waverly group" has been variously used to include the rocks from the base of the Berea sandstone to the top of the Logan formation and that some writers have included the Bedford shale and even the Cleveland shale in the Waverly. Ulrich (1912) went so far as to establish the Waverlyan system, which included all of the strata from the base of the Huron shale to the base of the Maxville limestone; this system, however, was rejected by the U. S. Geological Survey. Holden (1942) omitted the term "Waverly", but Weller and others (1948, p. 160; pl. 2) used the term "Waverly group" for the strata included in the Bedford, Berea, Sunbury, Cuyahoga, and Logan formations in south-central Ohio.

KINDERHOOK SERIES

BEDFORD SHALE

Definition

J. S. Newberry (1870, p. 21) applied the name "Bedford shale" to 60 feet of red and blue clay shale overlying the Cleveland shale and overlain by the Berea grit. The type area is at Bedford, Cuyahoga County.

Distribution

The Bedford shale is exposed only in the vicinity of Lithopolis, near the western border of Fairfield County. The southernmost exposures occur in section 18, Bloom Township, in tributaries of Big Run. North of Lithopolis it crops out in some of the westward-flowing tributaries of Walnut Creek and in the south bank of Walnut Creek in the SW$\frac{1}{4}$ of section 33, Walnut Township.

Drill records indicate that the Bedford is continuous throughout the subsurface of Fairfield County except in the deeper buried valleys in the western portion of the county where it has been removed by erosion.

Lithologic Character

On the outcrop, the Bedford shale usually consists of soft, blocky mudstone ranging in color from grayish red (10 R 4/2) to medium gray (N5) to brownish gray (5 YR 4/1). The mudstone is largely argillaceous, but it contains a small amount of silt and is slightly micaceous.

South of Lithopolis, in Big Run and its tributaries, more than 30 feet of grayish-red mudstone is overlain by 30 to 35 feet of medium gray or brownish-gray mudstone with a few thin siltstone ledges which commonly contain pyrite or marcasite. A covered interval 23 feet thick separates the lowermost outcrop of Bedford shale from the highest exposure of Ohio shale in Big Run. In the southernmost outcrop studied (O. G. S. 14572), in a ravine located in the SW$\frac{1}{4}$ of section 18, Bloom Township, the gray mudstone develops enough fissility to be properly termed a shale. In another ravine (O. G. S. 14573), located half a mile to the north, the upper few feet contains scattered concretions with well-formed pyrite crystals.

At Lithopolis (O. G. S. 10591) only the upper 20 feet of the formation is exposed. Here the Bedford consists of gray mudstone identical in appearance with the gray mudstone of the more southerly outcrops.

North of Lithopolis in section 6, Bloom Township (O. G. S. 14606), the Bedford consists of 45 feet of typical red mudstone. A 5-foot covered interval separates the Bedford shale from the overlying Berea sandstone. The upper gray mudstone apparent farther south has thinned rapidly, or perhaps even disappeared. The base of the red mudstone is separated from the black Ohio shale by a 12-foot covered interval, which is unbroken except for a small exposure of light olive gray (5 Y 5/2) mudstone near the middle of the interval.

Samples from an oil well (O. G. S. sample No. 775) in section 15, Walnut Township, yield what is probably a fairly typical section of the Bedford shale. The formation consists of 73 feet of grayish-red (10 R 4/2) to dark reddish-brown (10 R 3/4) mudstone or shale underlain by 7 feet of dark greenish-gray (5 GY 4/1) to grayish-black (N2) shale and overlain by 10 feet of dark gray (N3) shale. The driller recorded a thickness of 12 feet for the lower gray shale.

A number of drillers' logs, from wells clustered mainly in Richland, Rush Creek, and Walnut Townships, show a sequence of red shale overlain and underlain by relatively thin gray shales. Pepper and others (1954, p. 26) have noted that in many places the red Bedford shale is overlain by a few feet of gray shale and that it is generally separated from the underlying Ohio shale by about 15 feet of gray shale.

Cuttings from an oil well (O. G. S. sample No. 438) in section 30, Amanda Township, show the Bedford to consist of 74 feet of brownish-gray (5 YR 4/1) shale, which in some places varies in color to greenish gray (5 G 6/1) and is overlain by 10 feet of medium light gray (N6) mudstone.

According to Pepper and others, "the red shale thins and grades into gray Bedford shale in Pickaway County, Ohio" (Pepper and others, 1954, p. 26). The section observed in the Amanda Township well presumably lies in the zone of transition between the red and gray facies of the Bedford shale.

Thickness

The thickness of the Bedford ranges from approximately 60 feet in northwestern Bloom Township to more than 100 feet in eastern Fairfield County. Neither the minimum nor the maximum thickness can be precisely determined on the basis of data presently available.

The contact between the Bedford and Ohio shales is exposed nowhere in Fairfield County. In section 6, Bloom Township (O. G. S. 14606), the interval between the exposures of the Ohio shale and the Berea sandstone is 62 feet. In this section, outcrops of Bedford shale occur in an interval of 52 feet, indicating a thickness of from 52 to 62 feet for the Bedford. In the southwest quarter of section 18, Bloom Township (O. G. S. 14572), the upper 66 feet of the Bedford is exposed, and a covered interval 23 feet thick separates the lowest exposure of Bedford shale from the highest exposure of Ohio shale. The thickness of the Bedford shale south of Lithopolis is, therefore, no less than 66 feet and no more than 89 feet. Still farther south a thickness of approximately 84 feet is suggested by cuttings from a well (O. G. S. sample No. 438) in section 30, Amanda Township.

A thickness of 100 feet or more was shown by Pepper and others (1954, pl. 7) for the red Bedford shale in a small area west of New Salem in eastern Walnut Township. A cluster of 18 oil wells in which the red Bedford shale is reported shows a thickness ranging from 71 to 104 feet in sections 14 and 23 of Walnut Township. In only 3 of the 18 well records, however, is a thickness of more than 85 feet recorded for the red Bedford shale. Furthermore, Pepper and others (1954, p. 26) pointed out that the thickness of the red Bedford shale is commonly overestimated in drillers' logs because the red shale becomes churned and mixed with the underlying gray shale. The Walnut Township well records, as well as those in Richland and Rush Creek Townships, suggest that the maximum thickness of the red Bedford is in excess of 70 feet, but probably something less than 100 feet in the eastern half of the county.

Subsurface information on the Bedford shale is scanty outside of Walnut, Rush Creek, and Richland Townships. Pepper and others noted that "the red shale thins and grades into gray shale in Pickaway County, Ohio" (Pepper and others, 1954, p. 26), and they (1954, pl. 7) placed the 50-foot isopach for the red Bedford shale slightly east of the western tier of townships in Fairfield County. This is in accord with the meager subsurface and outcrop data in the western portion of the county.

Well records in which the red shale as well as the subjacent and superjacent gray shales are distinguished indicate that in some places in eastern Fairfield County the total thickness of the Bedford is in excess of 100 feet. The greatest thickness reported is 114 feet in a well (land owner: Ira Rutherford - Charles Wagner; operator: Ralph Brothers, Inc.) in section 29, Rush Creek Township. A few records indicate a much greater thickness, but the writer regards these as erroneous.

Stratigraphic Relations

The Bedford shale overlies the Ohio shale with probable conformity and is overlain disconformably by the Berea sandstone. The nature of this disconformity is described in connection with the stratigraphic relations of the Berea sandstone (p. 21-22).

The Ohio-Bedford contact is covered in Fairfield County and in the nearby Franklin County ravines. The contact was studied by Hyde (1953, p. 29-34) in outcrops near Piketon in Pike County and near Bainbridge in Ross County. He concluded, in contrast to Orton (1874, p. 619, 620), that the Ohio-Bedford contact in this area is not transitional and that the episodes of Ohio and Bedford deposition were separated by a brief erosional interval. Pepper and others (1954, p. 15) indicated that in some places between Berea, Ohio, and Irvine, Kentucky, the contact is transitional, but that in southern Ohio and northeastern Kentucky, it is distinct.

Pepper and others (1954), in a summary of data from thousands of well records, show that the red Bedford shale forms an elongate north-south-trending belt about 210 miles in length (fig. 5). Its northern boundary lies a few miles south of Lake Erie, and at its southern end the belt of red shale bifurcates into narrow lobes, one extending into Boyd County, Kentucky, and the other into Cabell County, West Virginia. Prior to its reduction in width by erosion, the belt was probably about 75 miles wide in northern Ohio and 60 miles wide in central Ohio. It narrows toward the south to a width of about 20 miles in Lawrence County, Ohio, where it bifurcates. The red shale belt is thickest along a north-south-trending line which passes through eastern Fairfield County. It thins to a feather edge to the east and west as well as toward its southern extremity.

The Bedford shale and Berea sandstone are persistent, lithologically distinct units in northern and central Ohio. In southern Ohio both formations grade into siltstones which are practically indistinguishable. The thickness of the combined Bedford and Berea formations at the Ohio River is 125 feet. In a stratigraphic section at Petersville, Kentucky, 18 miles south of the Ohio River, the siltstones have been replaced by 46 feet of soft, bluish-gray shale called the Petersville shale (Morse and Foerste, 1912, p. 24, 25). Approximately 60 miles farther south at Irvine, Kentucky, the gray shales of Bedford and Berea age thin to a feather edge, and the Ohio shale is overlain by the black Sunbury shale.

Age

The Bedford shale is involved in the controversy over the position of the Devonian-Mississippian boundary and has been assigned to the Devonian system by some writers and the Mississippian system by others. The boundary problem has been summarized by Schuchert (1943, p. 564-570). Among the more recent students of the problem, Campbell (1946) correlated the Bedford with the upper part of the New Albany shale of Indiana, which he considers to be of Kinderhook age. Hass (1947) considered the Bedford to be intermediate in age between the upper and lower portions of the New Albany and classified it as Devonian or Mississippian. Pepper and others (1954, p. 12) concluded that the most marked break in the interval between the base of the Ohio shale and the top of the Sunbury shale occurs at the Ohio-Bedford contact, making the Bedford the most logical choice of formations for the basal Mississippian unit in Ohio. The writer has no new data to contribute to the controversy and chooses to follow Weller and others (1948) in classifying the Bedford as early Mississippian (Kinderhook) in age.

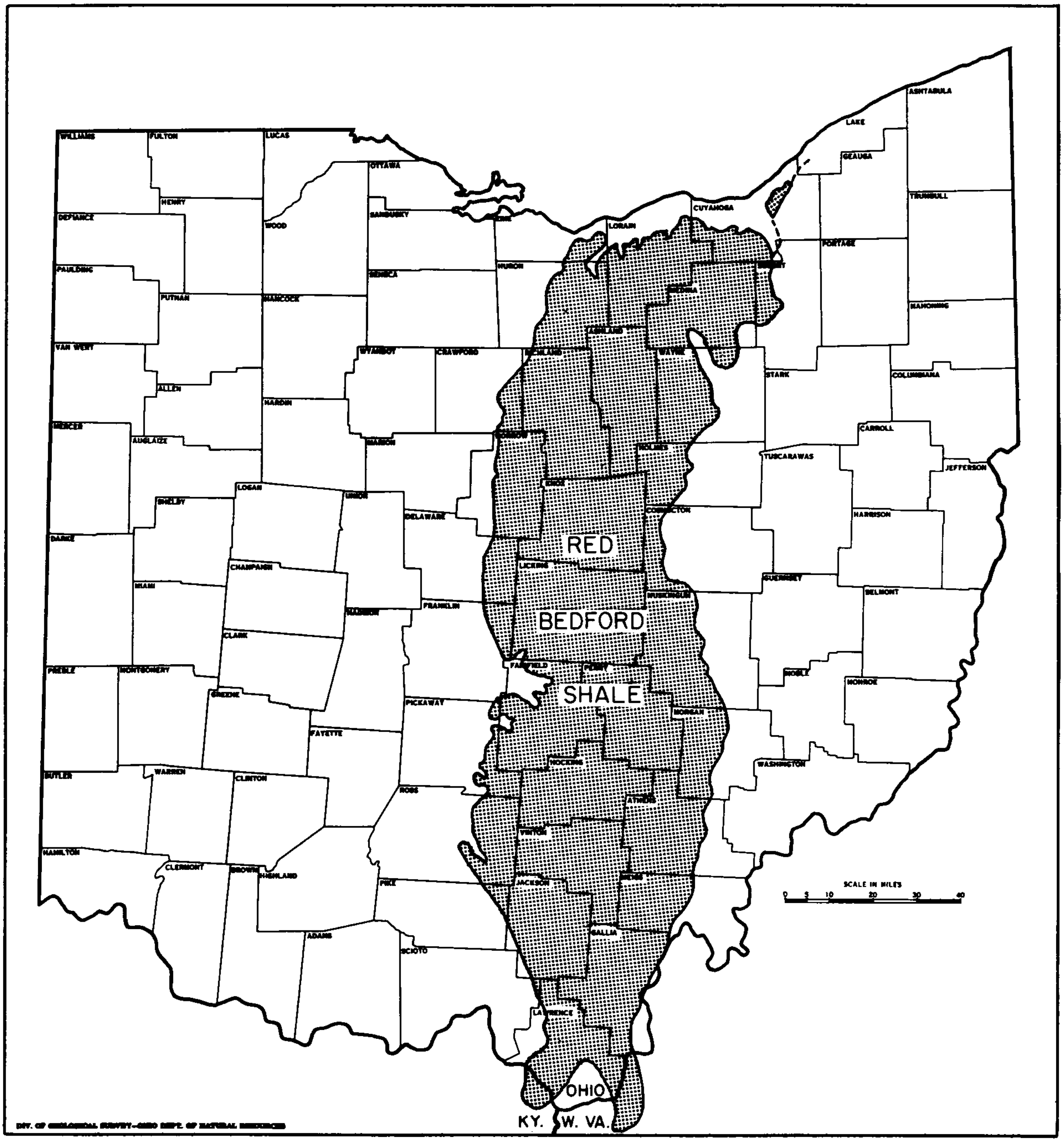


Figure 5. - Distribution of the red Bedford shale in Ohio, Kentucky, and West Virginia (after Pepper and others, 1954, pl. 7, modified).

BEREA SANDSTONE

Definition

The name "Berea grit" was applied by J. S. Newberry (1870, p. 21, 29) to 50 feet of drab sandstone overlying the Bedford shale and underlying the Cuyahoga shale. As used by Newberry, the Berea included the overlying Sunbury shale, which was later separated and considered a distinct formation by Hicks (1878, p. 216-220).

Distribution

The Berea sandstone in Fairfield County is exposed only in the ravines located in sections 6, 7, and 18, Bloom Township. Subsurface data indicate its presence everywhere in Fairfield County except immediately west of the outcrop area and in the deeper buried valleys in the western part of the county where it has been removed by erosion.

Lithologic Character

The Berea sandstone consists of very fine grained quartzose sandstone. The colors noted on the outcrop include olive gray (5 Y 4/1), dark greenish gray (5 GY 4/1), grayish orange (10 YR 7/4), and light brown (5 YR 5/6). Weathered surfaces are commonly iron stained. Cuttings from a well (O. G. S. sample No. 438) in section 30, Amanda Township, show two colors, medium light gray (N6) and pale reddish brown (10 R 5/4). Aggregates of the pale reddish-brown sand grains are calcareous. Very pale orange (10 YR 8/2) cuttings from a well (O. G. S. sample No. 775) in section 15, Walnut Township, are also slightly calcareous.

In the ravines in which it crops out in Bloom Township the Berea sandstone may be either medium bedded or massive. It is a hard, ledge-forming unit which commonly forms waterfalls where it occurs in stream beds. Pyrite and marcasite are common, and the sandstone is occasionally slightly micaceous. Oscillation ripple marks trending N. 70° W. were noted at both the northern and southern ends of the outcrop area (fig. 6).

Thickness

In western Bloom Township, where it is exposed, the Berea sandstone ranges in thickness from 3 to 8 feet. Pepper and others, in a compilation of well record data (1954, pl. 1), have shown that the Berea sandstone in Fairfield County thickens eastward, reaching thicknesses in excess of 40 feet in portions of Greenfield, Richland, Rush Creek, and Berne Townships. A perusal of drillers' records by the writer revealed that thicknesses in excess of 40 feet are infrequently reported. The greatest known thickness, 58 feet, was noted in the records of two wells, one in section 11, Greenfield Township (Murray Starner, No. 1), and the second in section 22, Rush Creek Township (David Merckle, No. 2).

Figure 6. - Oscillation ripple marks in the Berea sandstone in section 6, Bloom Township (O. G. S. 14606). Ripple mark crests trend N. 70° W. Pole, marked in tenths of feet, and pencil give scale.

Stratigraphic Relations

The Berea sandstone rests disconformably on the Bedford shale and is overlain with apparent conformity by the Sunbury shale. The Berea-Sunbury contact is described on page 24 of this report.

The sharp and disconformable contact between the Bedford shale and Berea sandstone is readily recognized in the field because the relatively hard Berea sandstone forms a prominent ledge where undercutting by streams has removed the easily eroded Bedford shale. The disconformable nature of the contact is well shown in the section at Lithopolis (O. G. S. 10591).

An excellent exposure of the contact occurs approximately a mile south of Lithopolis in a ravine in the NW$\frac{1}{4}$ of section 18, Bloom Township (O. G. S. 14573). At this outcrop (fig. 7) a 3-foot ledge of Berea sandstone forms the lip of a small waterfall. Directly beneath the sandstone ledge, but separated from it by 5 inches of Bedford-like mudstone, is a body of sandstone which is lithologically identical with the overlying ledge. The entire thickness and width of the lower sandstone body is shown in a vertical exposure at right angles to the stream bed. The maximum thickness of the lower sandstone is 5 feet. The base is in sharp contact with the underlying Bedford mudstone, and it rises rapidly, causing the sandstone body to feather out at its edges. The base of the sandstone is convex downward. The widest part of the lower sandstone body occurs at its upper surface, which is flat and approximately 50 feet in width. The shape suggests that the outcrop of the lower sandstone represents a cross section of a small channel deposit.

There is some question as to whether the lower sandstone should be considered to be of Berea or Bedford age. Pepper and others (1954, p. 56) point out that the sand in channels of Berea age is very similar to the sand in channels of Bedford age; the two may not always be distinguishable. Some attempt, however, has been made to separate the two on the basis of stratigraphic position in northern

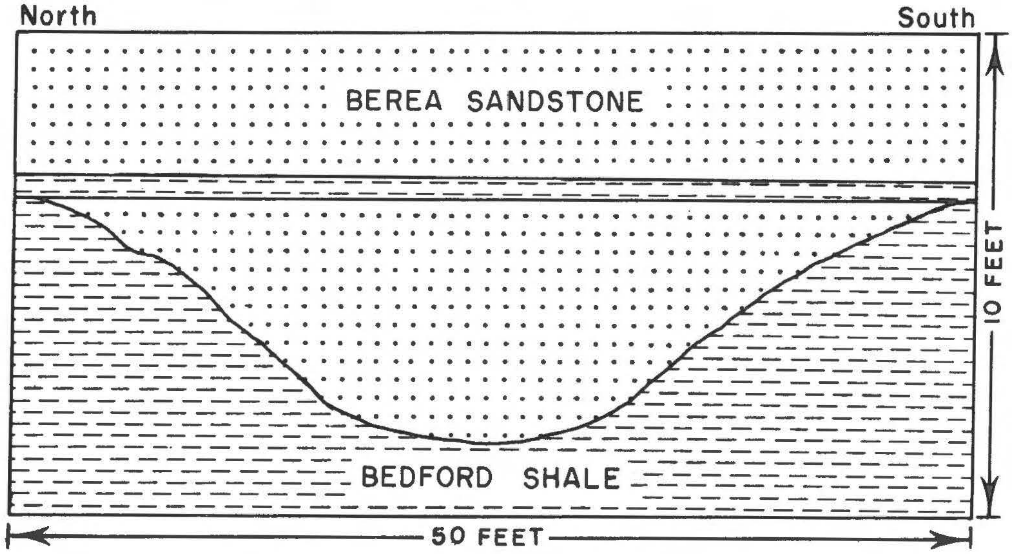


Figure 7. - Bedford-Berea disconformity in the NW$\frac{1}{4}$ of section 18, Bloom Township (O. G. S. 14573).

Ohio: "The best criterion for separating these sands is the presence of more than 10 feet of red shale above the channel sand of Bedford age. A thin covering of red shale might result from local erosion and redeposition of red shale during Berea time, but a thick cover of red shale could have originated only during Bedford time" (Pepper and others, 1954, p. 56). The lithologic similarity of the upper and lower sandstones in the Fairfield County outcrop, and the slight thickness of the mudstone which separates them suggest that the lower sandstone is probably of Berea age.

In northern and central Ohio the Berea sandstone rests on the underlying shales with marked disconformity. In southern Ohio the Berea is represented by siltstones which are virtually indistinguishable from the siltstones of the Bedford, and the disconformable relationship is lost. At Petersville, Kentucky, 18 miles south of the Ohio River, the Bedford and Berea are represented by 46 feet of soft, bluish-gray shale which Morse and Foerste (1912, p. 24, 25) named the Petersville shale. At Irvine, Kentucky, approximately 60 miles farther south, the Petersville shale feathers out, and the Ohio shale is overlain by the Sunbury shale.

Age

Weller and others (1948), following Campbell (1946) and Hass (1947), correlated the Berea sandstone with the upper part of the New Albany shale of Indiana and classified it as Kinderhook (early Mississippian) in age.

SUNBURY SHALE

Definition

L. E. Hicks (1878, p. 216, 220) used the name "Sunbury black slate" for exposures of 10 to 15 feet of black bituminous shale overlying the Sunbury Calciferous Sandrock (Berea sandstone in upper part) and underlying the Raccoon shales (Cuyahoga formation), at Sunbury in Delaware County, Ohio. The name "Sunbury shale," as used in this report, is equivalent to Hicks' Sunbury black slate.

Distribution

The Sunbury shale is exposed in Fairfield County only near the western border, in sections 6, 7, and 18 of Bloom Township, where it crops out in many of the ravines. Drill records indicate its occurrence everywhere in the subsurface of Fairfield County except immediately west of the outcrop area and in the deeper buried valleys where it has been removed by erosion.

Lithologic Character

The Sunbury shale is a black (N1) or grayish-black (N2), fissile, brittle shale. In some exposures the weathered surface is iron stained. A small amount of pyrite is present in well cuttings. The only exposure of the base of the Sunbury occurs in a ravine in the NE$\frac{1}{4}$ of section 6, Bloom Township (O. G. S. 14604). Here the Sunbury rests with sharp contact on the Berea sandstone, and abundant sand occurs in the lowest inch of the Sunbury shale.

Thickness

The entire thickness of the Sunbury shale is not exposed anywhere in Fairfield County. In the sections at Lithopolis (O. G. S. 10591) and in the southern half of section 18, Bloom Township (O. G. S. 14572), 28 feet of black shale is exposed, and the interval between the highest exposure of Berea sandstone and the lowest exposure of the Cuyahoga formation is 31 feet. In the northern half of section 18, Bloom Township (O. G. S. 14573), 17 feet of Sunbury shale is exposed, and a covered interval of 7 feet separates the Sunbury from the uppermost exposed Berea sandstone. Presumably the Berea sandstone is almost entirely exposed; a thickness of 24 feet is indicated for the Sunbury shale. In the NE$\frac{1}{4}$ of section 6, Bloom Township (O. G. S. 14606), the interval between the uppermost exposure of Berea sandstone and the lowest exposure of the Cuyahoga formation is 23. 5 feet. A covered interval of 10 feet separates the Sunbury shale from the Cuyahoga formation. The minimum possible thickness of the Sunbury shale in western Bloom Township, where it is exposed, ranges from 13. 5 to 28 feet; the maximum possible thickness ranges from 23. 5 to 31 feet.

In the subsurface the Sunbury shale tends to thicken slightly to the east. Cuttings from a well (O. G. S. sample No. 438) in section 30, Amanda Township, indicate a thickness of about 31 feet for the Sunbury shale. This is consistent with the thickness noted at the outcrops 8 to 10 miles to the north in the Lithopolis area. The remainder of the subsurface data on the Sunbury shale in Fairfield County has been taken from drillers' logs. East of the western tier of townships the thickness of the Sunbury shale appears to range from 25 to 60 feet. In a few instances thicknesses of appreciably less than 25 feet or greatly in excess of 60 feet have been recorded. These are presumed to represent errors in the well records.

Stratigraphic Relations

The Sunbury shale lies with probable conformity between the Berea sandstone below and the Cuyahoga formation above. The upper contact is discussed in connection with the stratigraphic relations of the Raccoon member (p. 44-45).

The Berea-Sunbury contact was observed in only one outcrop; elsewhere the contact is covered. In its single exposure, located in the NE$\frac{1}{4}$ of section 6, Bloom Township (O. G. S. 14606), the contact is sharp, but the basal inch of the Sunbury contains abundant sand grains.

In central and southern Ohio the Sunbury shale is a distinct formation readily separated from the underlying and overlying strata because of its black color and fissility. It becomes difficult to distinguish from the overlying shales of the Cuyahoga formation in northern Ohio and is included there as the basal unit of the Cuyahoga. Near Irvine, Kentucky, the equivalent of the underlying Berea and Bedford formations feathers out, and the Sunbury shale rests directly on the black Ohio shale. South of Irvine the combined Ohio and Sunbury shales are known as the Chattanooga shale.

Age

No fossils were observed by the writer, but Hyde (1912, p. 208) has reported *Lingula* and *Lingulodiscina* in the lowermost beds of the Sunbury in the ravine at Lithopolis. The base of the formation at this locality (O. G. S. 10591) is presently under water.

Campbell (1946) correlated the Sunbury shale with the upper part of the New Albany shale of Indiana, which he regarded as Kinderhook in age. Hass (1947, p. 136, 137) noted the occurrence of several identical conodont species in the Sunbury of central Ohio and in the Bushberg sandstone and Hannibal shale of the upper Mississippi Valley. Weller and others (1948) correlated the Sunbury shale with the Bushberg sandstone and Hannibal shale, which are of medial Kinderhook (early Mississippian) age.

KINDERHOOK AND OSAGE SERIES

CUYAHOGA FORMATION

Definition

J. S. Newberry (1870, p. 21) applied the term "Cuyahoga shale" to 150 feet of dove-colored shale and fine blue sandstone overlying the Berea grit and underlying the Maxville limestone. The type section is exposed along the Cuyahoga River between Akron and Cleveland.

As presently used in central Ohio, the term "Cuyahoga formation" includes a sequence of sandstones and shales which overlies the Sunbury shale and is overlain by the Logan formation.

Distribution

The Cuyahoga formation is present everywhere in Fairfield County except where it has been removed by erosion in western Bloom Township and in the deep buried valleys in the western portion of the county. It lies below drainage in Richland and Rush Creek Townships, which lie along the eastern border of the county. The formation is undoubtedly present in most of northern Fairfield County, but it is covered by a thick deposit of glacial drift.

Lithologic Character

Two rock types, which are in part facies equivalents, dominate the Cuyahoga formation. The finer grained facies consists of thin siltstones or sandstones interbedded with shales or mudstones. These beds are mainly gray or bluish gray in fresh exposures and show various shades of brown, yellow, or olive where weathered. The lithologic character of the finer grained facies is described in detail in the lithologic description of the Raccoon member (p. 36-42).

The coarser grained facies consists of massive, crossbedded sandstone which is medium to very coarse grained and in places conglomeratic. Its color ranges through several shades of brown, yellow, and red. More details are given in the description of the lithologic character of the Black Hand member (p. 46-54).

Transitional between the two lithologic extremes are thin-bedded, fine-grained sandstones. These are described later as Cuyahoga formation, undifferentiated (p. 63-64).

Thickness

The thickness of the Cuyahoga formation ranges from about 450 feet in eastern Rush Creek Township to approximately 650 feet in southeastern Hocking Township. Its thickness decreases west of central Fairfield County because of removal of the upper portion by erosion.

Stratigraphic Relations

The Cuyahoga formation lies conformably above the Sunbury shale and is overlain with probable slight disconformity by the basal beds of the Logan formation. The contact with the underlying Sunbury shale is gradational in some localities. In northern Ohio the Sunbury shale is included as the basal unit of the Cuyahoga, and the Cuyahoga formation rests directly on the Berea sandstone. To the south the Cuyahoga is continuous with the shale and siltstone of the New Providence formation of Kentucky (Stockdale, 1939, p. 99, 100).

The Cuyahoga formation in Ohio is especially notable for its complex and interesting facies relationships. The formation is primarily a body of shale, but three elongate, north-northwest-trending tongues of coarse-grained sandstone and conglomerate, which replace the upper part of the shale, are exposed in Hocking and Fairfield Counties; Licking, Knox and Richland Counties; and Wayne County (fig. 9).

J. E. Hyde was the first worker to recognize the facies relationships present within the Cuyahoga formation of Ohio. He has summarized his facies classification as follows:

> The Cuyahoga formation may be made up very largely of shales in one area but of sandstones and conglomerates in adjacent areas at no great distance. Furthermore, in any such area, the sediments are likely to remain much the same from the bottom of the formation to its top. That is, in a sandstone or conglomerate area we may expect to find sandstone or conglomerates or sandy shales more or less continuously throughout the formation, and in a shale area the sandstones are likely to be thin or inconspicuous. This is due to localized conditions of sedimentation which prevailed during Cuyahoga time. The result is that distinct depositional facies can be recognized with pronounced uniformity in the lithology of the vertical column in any one area, except in the regions of transition from one facies to the adjacent one.... Within these facies, the Cuyahoga is composed of distinct lithological members, which can be traced in regular succession over much or all of the facies and sometimes into adjacent facies. (Hyde, 1915, p. 664, 665)

Five north-northwest-trending facies were recognized by Hyde (1915, p. 665) in central and southern Ohio. From Licking County to the Ohio River these are (1) the Toboso facies, consisting largely of conglomerates and sandstones; (2) the Granville facies, composed mainly of shales; (3) the Hocking Valley conglomerate facies; (4) the Scioto Valley shale facies; and (5) the Vanceburg sandstone facies, consisting of relatively thin alternating beds of fine-grained sandstone and shale. The subdivisions of the Cuyahoga formation proposed by Hyde in 1915 are summarized in table 1. The distribution of Hyde's facies, as well as those named by Holden (1942) in northern Ohio, is shown on the map in figure 8.

In 1921 Hyde modified his earlier classification by considering the Berne member to be the basal unit of the Logan formation and correlating it with the Buena Vista member west of the Scioto River (Hyde, 1921, p. 152). Stockdale (1939, p. 131) and Fagadau (1952, p. 12, 13) considered this correlation to be erroneous and reaffirmed Hyde's earlier (1915) classification.

Holden (1942, p. 62) followed Hyde's 1921 correlation and considered the Buena Vista member the basal unit of the Logan formation in western Scioto County. He combined the Scioto Valley shale facies and Vanceburg sandstone facies into the Henley shale facies (1942, p. 42) and extended the facies classification into northern Ohio (1942, p. 44) with the addition of the Killbuck shale facies, River Styx conglomerate facies, and Tinkers Creek shale facies. Table 2 summarizes the stratigraphic subdivision of the Cuyahoga formation as proposed by Holden (1942).

Later writers have proposed several modifications of Holden's scheme. Fagadau (1952) re-established Hyde's (1915) Vanceburg and Scioto Valley facies and assigned the Buena Vista, Rarden, Vanceburg, Churn Creek, and Portsmouth members, as well as the Henley member, to the Cuyahoga formation. Szmuc (1957) enlarged upon the classification of the Cuyahoga formation in Holden's Tinkers Creek shale facies by recognizing the Strongsville member below the Meadville member and by dividing the Orangeville member into three submembers, in ascending order, the Sunbury, Aurora, and Chardon submembers. He raised the Rittman

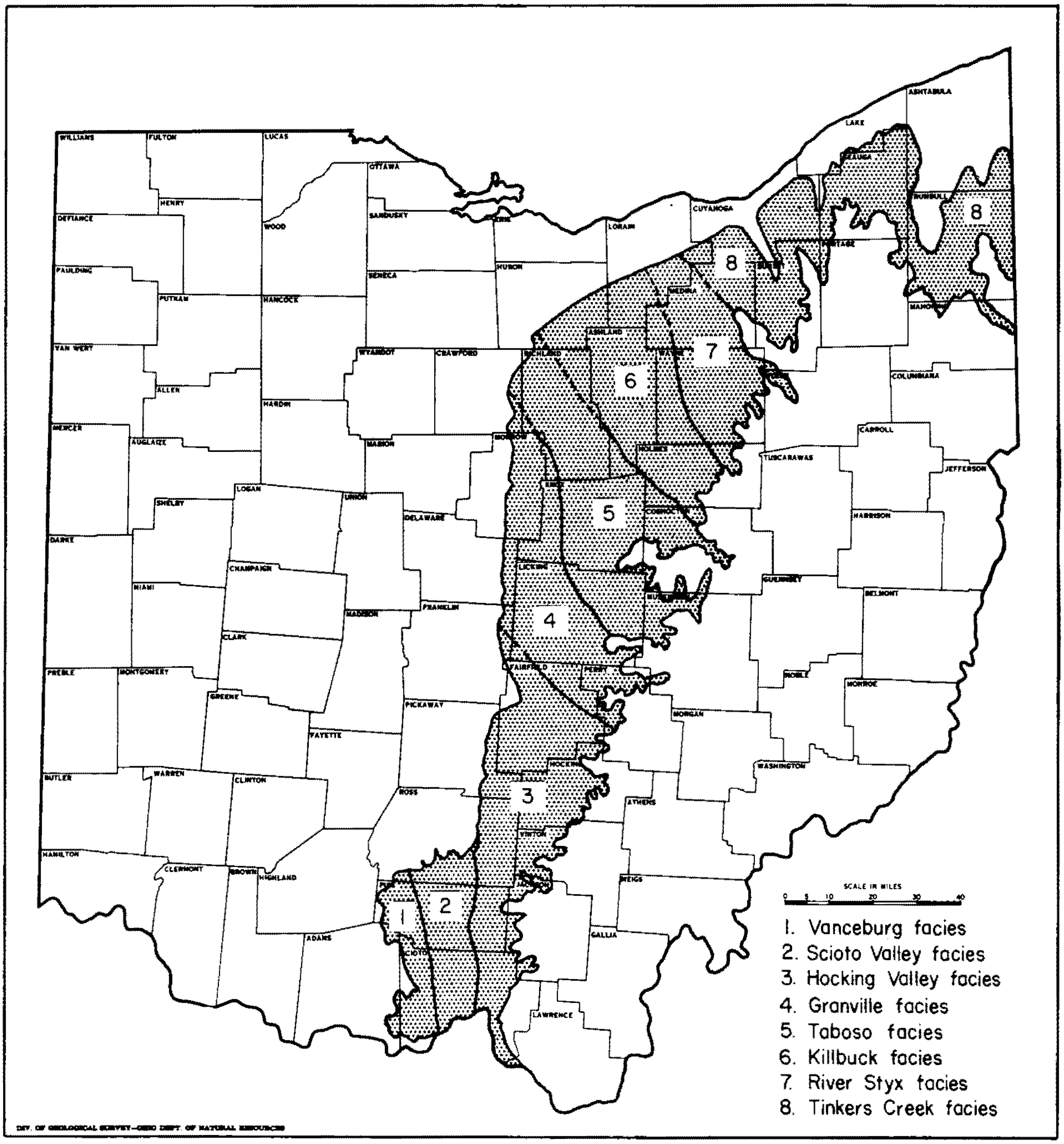


Figure 8. - Facies of the Cuyahoga formation (after Hyde, 1915, fig. 1; and Holden, 1942, fig. 2).

Table 1. - SUBDIVISION OF THE CUYAHOGA FORMATION PROPOSED BY HYDE IN 1915

Central Fairfield and Hocking Counties Hocking Valley conglomerate facies	Central Licking County Granville shale facies	Eastern Licking County Toboso conglomerate facies
Berne member	Berne member	Berne member
Black Hand member	Black Hand member	Black Hand member
Fairfield member	Raccoon shales	"Sandstones" (wells)
Lithopolis member		"Shales" (wells)

Southwestern Scioto County Vanceburg sandstone facies	Central Ross, Pike, and Scioto Counties Scioto Valley shale facies
Churn Creek member	Portsmouth member
Vanceburg member	
Rarden member	
Buena Vista member	Buena Vista member
Henley member	Henley member

Table 2. - SUBDIVISION OF THE CUYAHOGA FORMATION PROPOSED BY HOLDEN

Henley shale facies

- Henley shale member

Hocking Valley conglomerate facies

- Black Hand conglomerate member
- Fairfield sandstone member
- Lithopolis siltstone member

Granville shale facies

- Black Hand siltstone member
- Raccoon shale member

Toboso conglomerate facies

- Black Hand conglomerate member
- Pleasant Valley shale and sandstone member

Killbuck shale facies

- Black Hand shale member
- Armstrong sandstone member
- Burbank shale and sandstone member

River Styx sandstone facies

- Black Hand sandstone member
- Armstrong sandstone member
  - Rittman conglomerate submember

Tinkers Creek shale facies

- Meadville shale member
- Sharpsville sandstone member
- Orangeville shale member
  - Aurora sandstone submember

conglomerate of Holden's River Styx sandstone facies from submember to member status and introduced the term "Wooster member" as a substitute for Black Hand shale in the Killbuck shale facies. In the latter modification he was followed by Root (Root and others, 1961). Holden (1942, p. 48) introduced the name "Pleasant Valley member" for interbedded shale and sandstone lying directly beneath the Black Hand member in Richland County (Toboso facies); he also noted the occurrence of this member in Licking County. Root (Root and others, 1961) noted similar beds in western Knox County (Toboso facies) to which he applied the informal name "Cuyahoga siltstone and shale". He noted that these beds marked the transition from the coarse Black Hand sandstone to the underlying shales of the Cuyahoga formation, but preferred not to give them member status because poor exposure made their stratigraphic position uncertain and prevented his tracing them into the type section of Holden's Pleasant Valley member.

The writer suspects that the practice followed by Hyde and Holden of dividing the entire thickness of the Cuyahoga into provinces dominated alternately by fine- and coarse-grained clastic rocks may be slightly misleading. Root (Root and others, 1961) showed on the basis of well cuttings that the lower portion of the formation in the region denoted as the Toboso facies consists of shale. The present writer finds that the conglomerates and sandstones of the Hocking Valley region are similarly underlain by fine-grained clastic rocks in Fairfield and Hocking Counties. The Cuyahoga formation appears to be primarily a body of fine-grained clastic rocks which is partly replaced in some areas by the development of a sandstone and conglomerate facies. The continuity of the fine clastic rocks is shown in their occurrence in the lower part of the Cuyahoga formation in the Toboso and Hocking Valley regions.

Ver Steeg (1947, fig. 3) has shown on the basis of subsurface data that the coarse sandstone of the River Styx area merges with the sandstone and conglomerate of the Toboso region just north of the intersection of Licking, Knox, and Coshocton Counties. The conglomerates and sandstones of the Hocking Valley region similarly merge with those of the so-called Toboso facies in northern Marion Township, Hocking County. Collectively, the coarse sandstones and conglomerates constitute the Black Hand member of the Cuyahoga formation. The three conglomerate facies of Holden (1942) appear to be tongues of Black Hand sandstone merging to the south into a single body of Black Hand sandstone (fig. 9). The great length of these tongues, as compared to their width, results in a pronounced lobate shape. It seems advantageous to use the names "Hocking Valley", "Toboso", and "River Styx" to identify only the three lobate tongues of Black Hand sandstone and not the entire thickness of the Cuyahoga formation in the areas where the Black Hand member is developed.

Age

Weller and others (1948) correlated the Cuyahoga formation with the upper part of the Kinderhook series and the lower part of the Osage series of the upper Mississippi Valley. Little direct evidence of the age of the Cuyahoga formation is presently available in Fairfield County. However, faunal studies in the subjacent and superjacent strata and in the Cuyahoga formation in Knox County and in northeastern Ohio support this correlation.

Hass (1947, p. 136, 137) noted the occurrence of several identical species of conodonts in the Sunbury shale of central Ohio and the Bushberg sandstone and Hannibal shale, which are considered to be of medial Kinderhook age. Fagadau (1952, p. 147) suggested that the upper part of the Cuyahoga formation in central and southern Ohio is of probable early Burlington (medial Osage) age. Rodriguez

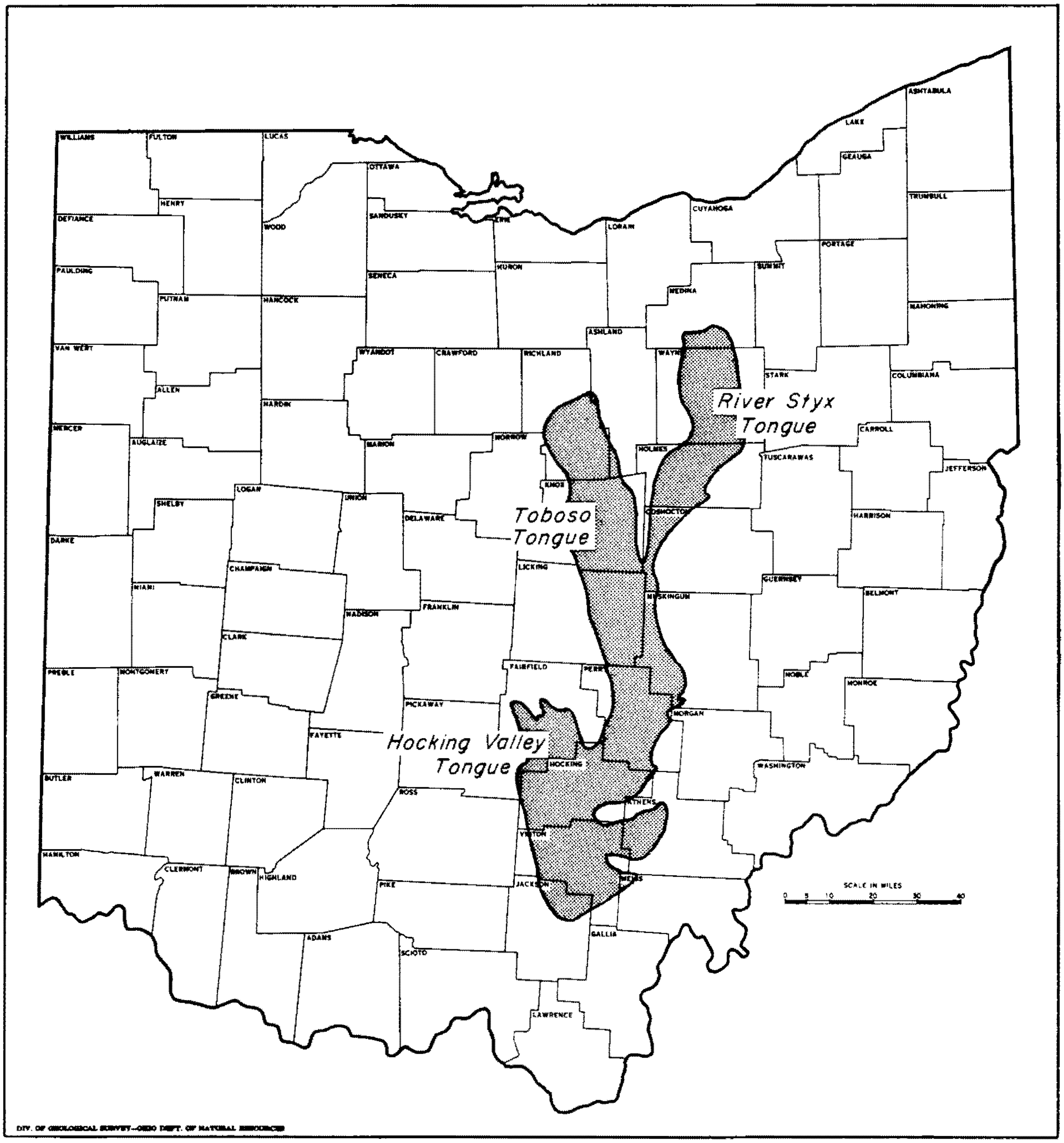


Figure 9. - Distribution and subdivisions of the Black Hand sandstone in Ohio (after Ver Steeg, 1947, fig. 3, modified).

(1957, p. 15) indicated a possible Fern Glen or Lower Burlington equivalence for the Wooster shale (upper part of the Cuyahoga) in Knox County. Szmuc (1957, p. 229) concluded that the Cuyahoga formation of northeastern Ohio is partly Kinderhook and partly Osage in age, but that the boundary between the two series is not distinct. The present writer concludes with relative assurance, therefore, that the Cuyahoga formation in Fairfield County is early Mississippian in age and contains equivalents of both the Kinderhook and Osage series.

Subdivisions

General Statement

Hyde (1915, p. 670-678) divided the Cuyahoga formation in his Hocking Valley conglomerate facies (Fairfield and Hocking Counties) into four members, in ascending order, Lithopolis, Fairfield, Black Hand, and Berne members. The Berne member subsequently was removed from the Cuyahoga formation and included as the basal member of the overlying Logan formation (Hyde, 1921, p. 154). A summary of Hyde's observations follows:

> The Lithopolis member.... is a series of thin, horizontally bedded sands and shales exposed in the northwestern part of Fairfield County in the vicinity of Lithopolis. The sandstones are light gray, bluish or brown in color, moderately fine grained and evenly bedded. The shales are argillaceous, sometimes sandy, and commonly gray in color. The sandstones and shales, on the whole, are about equal in amount, although the sandstones tend to be more abundant in the upper part. The thickness of the Lithopolis member varies from 118 to as much as 200 feet. In the area of maximum thickness between Lithopolis and Chestnut Ridge it is overlain by a massive, coarse, yellow sandstone which is wholly different from the sandstones of the Lithopolis member. (Hyde, 1953, p. 21)
>
> The Fairfield member.... is a series of reddish yellow, brown, or bluish gray massive sandstones in lentils 20 to 60 feet thick with intervening shales of similar thickness. The shales themselves are formed of thin interbedded sandstones and shales, the former likely to be coarse, even when thin. In some places the beds show initial dips to the northward from two to six degrees. The member is between 200 and 330 feet thick, but an exact determination of its thickness is not possible. (Hyde, 1953, p. 22)
>
> The Black Hand member.... is a coarse, massive sandstone distinguished from the underlying Fairfield member by the absence of shale and the increased prominence of structural features, notably steeply inclined bedding (10° to 20°), numerous erosion planes and abundant cross-bedding. Its thickness is about 100 feet, but it may reach 150 feet over the center of the province. This member extends laterally beyond the lower members. It persists to the eastward, with complete loss of structure (except normal bedding) into eastern Fairfield County where it passes below drainage. Westward it passes into sandstones and then into the Cuyahoga shales in eastern Ross and western Hocking and Vinton Counties. A marine fauna appears in the sandstones just east of where they pass into shales. The transition zone has been traced in a south-southeasterly direction from near the extreme northeast corner of Ross County to the south line of Vinton County.

> In the center of the province the Black Hand is composed of quartz pebbles which seldom exceed an inch and a half in diameter. Throughout most of its thickness the Black Hand is characterized by a northward inclination of the bedding at angles ranging commonly from 10° to 20°. This feature is more prominent on the eastern side of the area. The top 10-25 feet lie horizontally, suggesting the topset beds of a delta above the inclined foreset beds. There is an erosional plane between the Black Hand and Fairfield members at almost every place where the contact was observed, but this plane disappears near the margin of the facies where the coarse conglomerates give place to shale. The surface of the coarse accumulation at any given time stood well above the mud floor of the adjacent shale facies and was liable to erosion over portions of its surface under conditions which did not affect the adjoining deeper areas. (Hyde, 1953, p. 22)

The writer believes that the Cuyahoga formation in Fairfield County consists of two members, which are distinguished by striking differences in grain size. The fine-grained member consists of interbedded shales or mudstones and siltstones or fine-grained sandstones and is referred to in this report as the Raccoon member. The second member, called the Black Hand member, consists of medium-grained to very coarse grained and conglomeratic sandstone. The Raccoon member is in part subjacent to and in part laterally equivalent to the Black Hand member (fig. 4).

Beds consisting of fine-grained sandstone are thought to be transitional between the two members. They are mappable only on an extremely local basis and, therefore, are not considered a distinct member. The transition beds are denoted as Cuyahoga formation, undifferentiated.

The alternating shales and siltstones of Hyde's Lithopolis member are exposed only in northwestern Bloom Township. Removal by erosion, and lack of exposure due to the presence of overlying strata and glacial drift prevent their being traced on the outcrop in any direction from the Lithopolis area. The writer prefers to consider them as a part of the large body of fine clastic rocks for which the name "Raccoon member" is used.

The Fairfield member (Hyde, 1915, p. 671-672) consisting of massive sandstones 20 to 60 feet thick with intervening shaly strata of similar thickness was not recognized as a distinctive stratigraphic unit by the writer in Fairfield County. Hohler (1950), in Perry Township in northwestern Hocking County, and Hall (1951), in southern Hocking County, found no strata which fit Hyde's definition of the Fairfield member. Merrill (1950, p. 51-59) noted a sequence of alternating coarse-grained massive sandstones and thin- to medium-bedded sandstones with thin interbedded shales in Good Hope Township, Hocking County. Although the massive members averaged 10 feet in thickness and the bedded portions only 5 feet in thickness, Merrill assigned these strata to the Fairfield member.

The writer believes that Hyde's Fairfield member was named for a sequence of intertonguing shale and sandstone occurring in the zone of transition between the Black Hand and Raccoon members. The sandstones are lithologically indistinguishable from those of the Black Hand member and are included in the Black Hand. The intervening shales are classified as Raccoon. Strata similar to those described by Merrill have been observed in southern Fairfield County and are interpreted as local variations of the Black Hand member. According to this interpretation, the significance of the term "Fairfield member" is greatly different from that intended by Hyde, and the writer prefers not to use it.

Raccoon Member

Definition

The name "Raccoon shales" was proposed by L. E. Hicks (1878, p. 216, 219) for an estimated 300 feet of blue and gray shales overlying the Sunbury shale and overlain by the Black Hand conglomerate. The type section is located on Raccoon Creek in Licking County.

Hyde (1915, p. 681) noted that in the vicinity of Newark in Licking County 20 or 30 feet of sandy or clay shales with numerous thin sandstones is exposed below the Black Hand. The remainder of the Cuyahoga formation in the region is below drainage, but Hyde inferred from well records that the interval between the Sunbury and the Black Hand consists of 200 feet, more or less, of shale overlain by 200 feet of shale with numerous sandstone beds. He tentatively proposed that the term "Raccoon member" be used to designate the almost unknown thickness of shale and sandstone occupying this interval in his so-called Granville shale facies.

Merrill (1950, p. 66-70) applied the name "Raccoon member" to thin, interbedded shales, siltstones, and very fine grained sandstones lying below the Black Hand member in section 15, Good Hope Township, Hocking County. The writer has observed similar beds along the Hocking Valley in a number of outcrops between Lancaster and Clear Creek in section 15, Good Hope Township. Outcrop and subsurface data indicate that the shaly strata intertongue with coarse, massive sandstone which wedges out to the east. The shaly beds are tongues wedging out into the sandstones of the Black Hand member to the west and thickening rapidly to the east where they constitute most, if not all, of the thickness of the Cuyahoga formation. They are believed to be continuous with the beds which Hyde called Raccoon. Hyde's term "Fairfield member" probably applies to the alternating shales and sandstones occurring in the zone where the Black Hand and Raccoon members intertongue.

West of the Hocking Valley, in southern Hocking Township, drillers' logs indicate the presence of 120 to 138 feet of "slate" or "slate and shells" lying below the Black Hand member. Cuttings from a well (O. G. S. sample No. 641) located in section 17, Laurel Township, Hocking County, indicate that at least 120 feet of siltstone to very fine grained sandstone with a small amount of shale overlies the Sunbury shale. Farther north at Lithopolis in Bloom Township almost 120 feet of interbedded shale and siltstone occupy the interval between the Sunbury and Black Hand. Hyde (1915, p. 670, 671) referred these beds to his Lithopolis member. The writer believes that these beds are part of the larger body of fine-grained clastic rocks which has been called Raccoon farther east and proposes, therefore, to refer them to the Raccoon member.

In Clear Creek Township, to the west of the Hocking Valley tongue of the Black Hand member, the Cuyahoga formation is represented by dark shale or mudstone with thin interbedded sandstone. Similar beds have been described in western Hocking County by Hohler (1950) and Hall (1951) and in western Vinton County by Hyde (1927). Following Hyde (1927, p. 48, 49), Hall and Hohler referred to these beds as Cuyahoga shale. All three writers indicated that the shale thickened westward, occupying the stratigraphic position of the Black Hand member. The writer believes that these beds, too, are part of a larger body of fine-grained clastic rocks which lies between the Sunbury and Black Hand and is in part laterally equivalent to the Black Hand. The term "Cuyahoga-shale" is not a satisfactory name because it refers to a member in a formation of the same name. The writer, on the basis of presently available evidence, sees little advantage in distinguishing these strata from those elsewhere called Raccoon and tentatively proposes that they, too, be included in the Raccoon member.

The term "Raccoon member", as used by the writer, refers to a rather poorly known body of fine-grained clastic rocks lying immediately above the Sunbury shale and overlain by the Black Hand member or by transitional beds of thin- to medium-bedded, fine-grained sandstone (Cuyahoga formation, undifferentiated) which separate the Raccoon and Black Hand in some localities. The exact eastward extent of the uppermost portion of the Black Hand member in Fairfield County is unknown, but it is probable that in portions of eastern Fairfield County the Raccoon member occupies the entire interval between the Sunbury shale and the Logan formation.

Distribution

The Raccoon member is probably present everywhere in Fairfield County except in those localities in the western portion where post-Mississippian erosion has removed all of the strata above the Sunbury shale. Its distribution, therefore, is the same as that of the Cuyahoga formation (p. 25).

The surficial extent of the Raccoon is considerably less than that of the Cuyahoga formation because the Black Hand member occupies the stratigraphic position of the upper portion over most of the outcrop area of the Cuyahoga formation.

Exposures occur almost exclusively along the margins of the Hocking Valley tongue of the Black Hand member. Intermittent outcrops are present along the walls of the Hocking Valley in some road cuts and steep ravines. A lobe of the Hocking Valley tongue passes north through Lancaster, and occasional exposures of the Raccoon occur immediately east and north of its margins.

The most northerly exposure, and the only one not located immediately adjacent to the Black Hand member, occurs approximately 5 miles north of Lancaster in a tributary of Big Walnut Creek in the NE$\frac{1}{4}$ of section 12, Greenfield Township.

A second lobe of the Hocking Valley tongue passes northwest to Chestnut Ridge in north-central Bloom Township. The area between the two lobes of the Hocking Valley tongue is largely drift covered, but a few poor exposures in northern Hocking and southern Greenfield Townships indicate the presence of the Raccoon member.

Within the Hocking Valley tongue the Raccoon is represented by some thin tongues of shale which are exposed in a few of the ravines west of the Hocking Valley in Hocking, Madison, and Berne Townships.

The base of the Raccoon member is exposed only in the vicinity of Lithopolis in northwestern Bloom Township. Almost the entire interval between the Sunbury and the Black Hand is exposed in northern Bloom Township, but not in any one continuous section.

On the western margin of the Hocking Valley tongue of the Black Hand member, the Raccoon is exposed particularly well along Salt Creek in southern Clear Creek Township.

Lithologic Character

The Raccoon member consists generally of thin alternating beds of relatively soft mudstone or shale and relatively hard siltstone to fine-grained sandstone. Gray is the most common color in fresh exposures, but the member weathers to various shades of olive and brown. Although shale or mudstone commonly alternates in thin beds with siltstone or sandstone, either lithologic type may predominate, or even occur exclusively, in some portions of the member.

Most of the exposures of the Raccoon member are located along the flanks of the Hocking Valley tongue of the Black Hand member. In only one instance is the member thought to be exposed well outside of the zone of transition with the Black Hand. Approximately 5 miles north of Lancaster, along a tributary of Big Walnut Creek in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 12, Greenfield Township, 19 feet of thin alternating siltstones, mudstones, and sandstones is exposed. The siltstone is medium bluish gray (5 B 5/1), hard, and slightly micaceous; the mudstone is light olive gray (5 Y 5/2), blocky to thin bedded, silty, micaceous, and rather soft; the sandstone is dark yellowish orange (10 YR 6/6), very fine grained, thin to medium bedded, and micaceous. The Raccoon member at this locality lies in the stratigraphic interval occupied by the Black Hand member, which is well exposed at Mt. Pleasant, approximately 5 miles to the south.

Wells in eastern Fairfield County. - In eastern Fairfield County, where there are no bedrock exposures, or where only strata overlying the Cuyahoga are exposed, drillers' records yield some information on the nature of the Raccoon. Commonly reported are mud, slate, shale, and shells, occurring in various combinations. The term "shells" probably refers to thin, relatively hard beds of siltstone or sandstone interbedded with the shale. The color most commonly reported is gray, but blue, white, and black also have been reported in some well logs.

More detailed subsurface data are available in the cuttings of a rotary-drilled well (O. G. S. sample No. 676) located less than half a mile east of the Fairfield County line in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ of section 6, Jackson Township, Perry County. According to the writer's interpretation of the cuttings, the base of the Logan formation lies about 495 feet above the top of the Berea sandstone. The Sunbury shale cannot be distinguished from the Raccoon. Two lithologic types are represented in the samples. One consists of dark gray (N3) to light gray (N7) micaceous siltstone to very fine grained sandstone, and the other of dark gray (N3) to medium dark gray (N4), micaceous, slightly silty shale. The shale is absent in the upper 55 feet, and the siltstone to very fine grained sandstone is absent in the 90-foot interval immediately above the Berea. In the intervening 350 feet, siltstone to very fine grained sandstone is slightly more abundant in the samples. A few crinoid columnals were observed in the lowest 100 feet.

Almost 500 feet of strata belonging to the Cuyahoga formation is represented in cuttings from a well (O. G. S. sample No. 775) in section 15, Walnut Township. Overlain by 65 feet of drift is 147 feet of light gray (N7), very fine grained, slightly micaceous sandstone. A small amount of dark gray (N3), micaceous, silty shale or mudstone occurs in all of the samples taken in this interval. It comprises less than a third by volume of the sampled material except in the lower 18 feet, in which it constitutes about half of the sampled material.

Below the sandstone is 335 feet of dark gray (N3) to light gray (N7), slightly micaceous siltstone to very fine grained sandstone and grayish-black (N2) to medium dark gray (N4) mudstone or shale, which is slightly silty and micaceous. The coarser fraction predominates in the samples except in the uppermost 18 feet and the lowermost 12 feet, where it is absent. Thicknesses based on well cuttings are only approximations, their precision being dependent upon the positions and thicknesses of sampling intervals.

The underlying Sunbury is readily distinguished in the Walnut Township well cuttings because of its black (N1) color and its well developed fissility.

Road cuts and ravines in the Hocking Valley area. - The Raccoon member is exposed in a number of road cuts and ravines along the Hocking Valley between Lancaster and Clear Creek, which enters the Hocking Valley a short distance south of the Hocking-Fairfield County line. These exposures lie along the eastern margin of the Hocking Valley tongue of the Black Hand member. Because the lithologic character of the Raccoon is slightly variable, several of these exposures are described.

A good exposure of the Raccoon member occurs in a ravine known locally as Crystal Springs Hollow. The ravine is located in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 4, Berne Township (T. 13 N.), approximately half a mile directly west of the south end of the village of Sugargrove. A stratigraphic section (O. G. S. 14603) measured here shows 51 feet of interbedded shale and sandstone. The shale is light gray (N7), silty, micaceous, and soft. It occurs in layers ranging in thickness from about an inch near the top of the unit to a foot or more near the base. In sharp contact with the intervening shales are beds of medium light gray (N6), hard, very fine grained to fine-grained sandstone which in a few localities is iron stained. Flow casts are common, and some layers contain thin, thumbnail-sized lenses of argillaceous matter. The thickness of the sandstone layers ranges from half an inch to 12 inches; the beds are thinner and more widely spaced near the base of the unit and become thicker and more abundant in the upper portion. The sandstones are much more resistant than the intervening shales and tend to form small ledges along the stream banks and low falls in the stream bed.

A road cut (O. G. S. 14547) located 2 miles north of Crystal Springs Hollow in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ of section 28, Berne Township, shows excellently the upper portion of the Raccoon member and its relationship to the Black Hand sandstone, which overlies the Raccoon member here as well as on the east side of the Hocking Valley. The Raccoon in this outcrop (fig. 10) consists of 67 feet of medium gray (N5), micaceous, slightly silty mudstone and light olive gray (5 Y 6/1), hard siltstone. The two lithologic types occur in alternating beds ranging from a quarter of an inch to 3 inches in thickness, and the siltstone becomes increasingly abundant upward in the upper 25 feet of the member. Overlying the Raccoon with a gradational contact is at least 26 feet of fine-grained sandstone, which separates the Raccoon from the Black Hand.

An exposure located in a road cut on the west wall of the Hocking Valley in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 17, Berne Township (O. G. S. 14548) shows still another variation in the lithologic character of the Raccoon. Here 15 feet of mudstone overlies sandstone which probably represents a local tongue of the Black Hand (fig. 11). The mudstone is pale yellowish brown (10 YR 6/2) and is somewhat iron stained. It is blocky, crumbles easily, and contains some silt and mica; no siltstone or sandstone is interbedded. The contact with the Black Hand member below is covered.

Marine fossils were found in an outcrop of the Raccoon in a road ditch along the east-west road in the NE$\frac{1}{4}$ of section 30, Pleasant Township. Siltstone to very fine grained sandstone with a few intercalated mudstones or shales is exposed. The siltstone to very fine grained sandstone, which is grayish orange (10 YR 7/4) to pale yellowish brown (10 YR 6/2), is mottled by iron stains on weathered surfaces and contains a few brachiopods and pelecypods. The intercalated mudstone or shale is mottled, the color ranging from medium bluish gray (5 B 5/1) to moderate yellowish brown (10 YR 5/4). It is slightly micaceous and silty and occurs in beds up to 6 inches thick.

The Hocking Valley tongue of the Black Hand sandstone bifurcates in central Hocking Township into two small lobes. One passes north through Lancaster, and the other extends northwest into northern Bloom Township. Several poor exposures of the Raccoon member occur in the intervening "embayment." Two of these outcrops are described below.

A short distance west of Lancaster in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 2, Hocking Township, 2 feet of interbedded mudstone and sandstone was dug out of a road bank where the highway passes on the south side of a small hill. The sandstone is dark

Figure 10. - Alternating mudstone and siltstone of the Raccoon member in section 28, Berne Township (O. G. S. 14547).

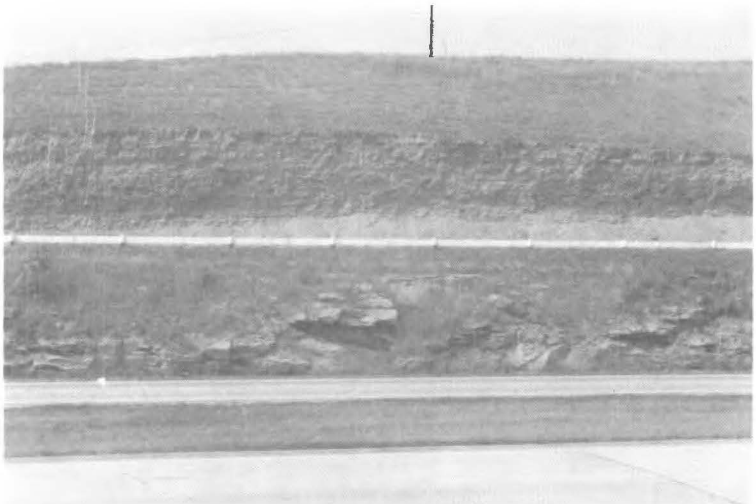


Figure 11. - Raccoon member overlying the Black Hand sandstone in section 17, Berne Township (O. G. S. 14548).

yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), very fine grained, hard, micaceous, and thin bedded. Alternating with it are layers of moderate yellowish-brown (10 YR 5/4), sandy, soft, blocky to thin-bedded mudstone containing abundant small carbonized fragments which may be plant remains.

Two miles west of the exposure described above, along the road in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ of section 8, Hocking Township, the Raccoon consists of 20 feet of soft, blocky, micaceous mudstone which is moderate yellowish brown (10 YR 5/4), slightly silty, and slightly carbonaceous. The mudstone is interrupted by a single 3-inch bed of grayish-orange (10 YR 7/4) to moderate yellowish-brown (10 YR 5/4), medium-grained, hard sandstone with abundant quartz overgrowths.

Ravines in western Fairfield County. - The Raccoon member appears in several outcrops west of the Hocking Valley tongue in south-central Clear Creek Township. The best exposure known to the writer, and one which may be considered representative, is located on the west bank of Salt Creek in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ of section 34, Clear Creek Township, about three-quarters of a mile northwest of the village of Tarlton (fig. 12). A stratigraphic section measured here (O. G. S. 14546) shows the Raccoon to consist mainly of medium dark gray (N4), slightly silty, micaceous, soft mudstone with scattered clay ironstone concretions. Alternating with the mudstone are beds of moderate yellowish-brown (10 YR 5/4), fine- to medium-grained, micaceous sandstone. Flow casts, as well as small carbonaceous fragments, are common on the bedding surfaces of the sandstone, and small clay galls occur at some places within it. The sandstone beds range from half an inch to 3 inches in thickness and are separated by 3 inches to 2 feet of mudstone. The thickness of the entire unit is 52 feet, and neither the top nor the bottom is exposed.

Fine-grained clastic rocks (Lithopolis member of Hyde) crop out in the ravines in the vicinity of Lithopolis and Chestnut Ridge in northern Bloom Township. An exposure (O. G. S. 10591) in sections 6 and 8, in a ravine located just northeast of the town of Lithopolis, may be considered representative. The Raccoon member is divided into two distinct units: a basal unit consisting of soft gray mudstone; and an upper unit consisting of alternating shale and siltstone or very fine grained sandstone.

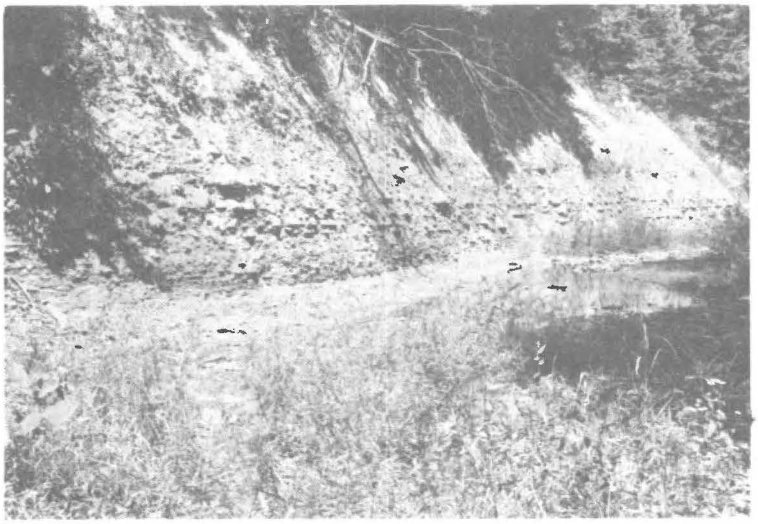


Figure 12. - Exposure of the Raccoon member with ledges of interbedded sandstone along Salt Creek, north of Tarlton (O. G. S. 14546).

The basal unit is 4.5 feet thick and consists of medium gray (N5) mudstone, which is iron stained on the weathered surface. The mudstone (fig. 13) is soft and blocky and contains small amounts of silt and mica. It rests with sharp contact on the underlying Sunbury shale. Small lenses of the mudstone up to an inch in diameter are embedded in the upper few inches of the Sunbury shale. In the only other section in which this contact is exposed (O. G. S. 14573), in section 18, Bloom Township, the gray mudstone grades downward into the Sunbury shale in a transition zone 1 to 2 inches in thickness.

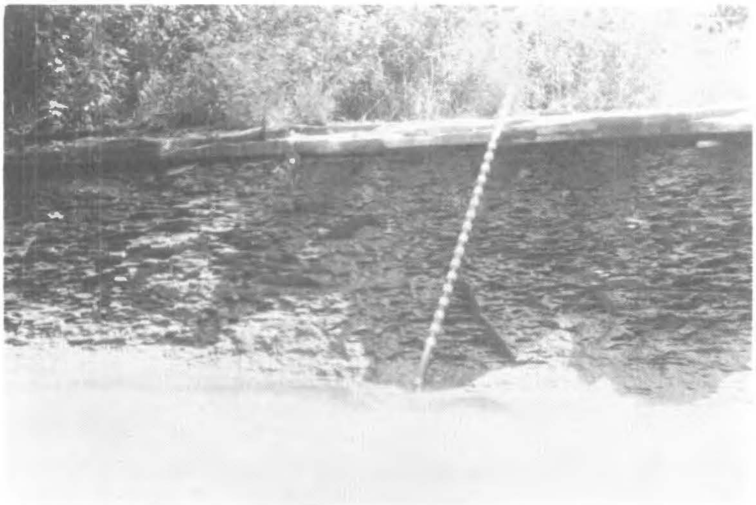


Figure 13. - Gray mudstone at the base of the Raccoon member near Lithopolis (O. G. S. 10591). The lip of the waterfall is formed by the lowest siltstone of the Raccoon. The pole is 5 feet long and is marked in tenths of feet.

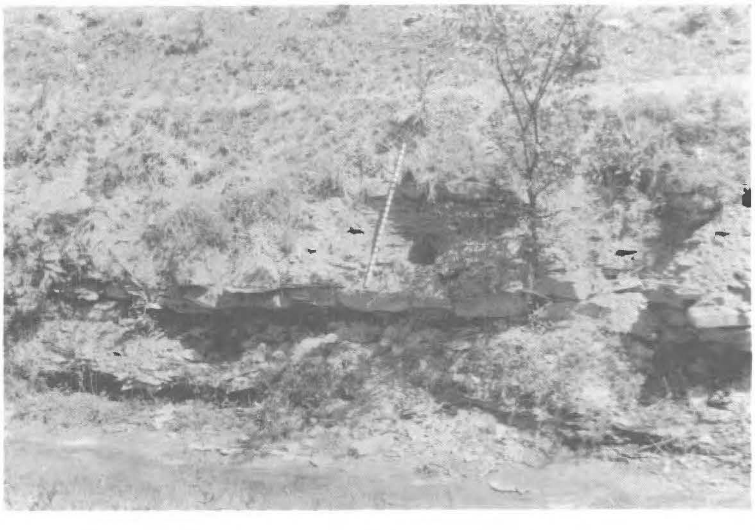


Figure 14. - Alternating siltstones and shales of the Raccoon member near Lithopolis (O. G. S. 10591).

Overlying the gray mudstone is a sequence of alternating siltstones or very fine grained sandstones and shales (fig. 14). The siltstones, which are hard and stand out as resistant ledges, are light olive gray (5 Y 6/1) to light bluish gray (5 B 7/1) and weather to various shades of olive and brown. They occur in massive beds up to 2 feet in thickness, but show some tendency to weather thin bedded. The base of the unit consists of such a siltstone ledge, which lies with sharp contact on the basal mudstone. Narrow winding ridges up to an eighth of an inch in width stand out on the lower surfaces of the massive beds, suggesting casts of worm trails in the underlying shales. Current ripple marks are common on the bedding surfaces of the siltstones. A set of ripple marks occurring 15 feet above the base of the unit indicates a current direction of N. 75° W. The massive siltstones rest with sharp contact on the intervening shales.

The resistant beds of massive siltstone grade upward into soft, light olive gray (5 Y 6/1), thin-bedded siltstone, which is argillaceous and contains abundant fragments of mica and carbonaceous material. The thin-bedded siltstone grades rapidly upward into soft shale, which is distinctive only because of the presence of fissility and decrease in silt content. The soft, thin-bedded portions of the unit range in thickness from 2 inches to 4 feet and are overlain with sharp contact by massive, resistant siltstones.

Wells in south-central Fairfield County. - Hyde noted the persistence of his Lithopolis member beneath the Black Hand to the south. "To the southward, beneath the central portion of the Hocking Valley province, the Lithopolis member is entirely below drainage but the well-drillers invariably report from 100 to 200 feet or even more of 'shale' at the base of the Cuyahoga" (Hyde, 1915, p. 670, 671).

The following section is taken from the driller's record of a well in section 33, Hocking Township (land owner: C. Soliday, No. 10; operator: C. S. Blauser):

Drift (32 feet)	
soft yellow sand and clay.	32 feet
Black Hand member (228 feet)	
white, hard sand rock.	228
Raccoon member (120 feet)	
black, soft mud.	18
white, hard and soft slate	84
black, soft mud.	18
Sunbury shale (47 feet)	
coffee shale	47
Berea sandstone	
(stratigraphic terms supplied by writer)	

Part of the record from a well located in section 34, Hocking Township (land owner: George R. Rockey; operator: City of Lancaster, Ohio) follows:

Black Hand member (332 feet)	
yellow sand rock	57 feet
red mud slate	5
red sand rock	205
yellow sand rock	40
white sand rock.	15

Raccoon member (138 feet)	
muddy blue slate.	70 feet
sandy shells and blue slate	55
hard brown shell.	3
blue slate.	10
Sunbury shale (32 feet)	
black slate	32

(stratigraphic terms supplied by writer)

Thickness

The total thickness of the Raccoon member is exposed nowhere in Fairfield County. At Lithopolis, where the Raccoon underlies the northern end of the Hocking Valley tongue of the Black Hand member, the exposed thickness is 85 feet. However, Lamb in 1906 in a personal letter to Hyde (Hyde, 1953, p. 93) reported that the upper contact of the member with the overlying Black Hand was exposed 118 feet, 7 inches above the base of the Cuyahoga formation in the road by the cemetery just south of the village of Lithopolis.

Between 2 and 3 miles east of Lithopolis the Black Hand member is exposed along Chestnut Ridge. In this area the base of the Raccoon is well below drainage and the top is not exposed. The approximate position of the top of the member may be inferred, however, from the position of the lowest outcrops of Black Hand and the highest outcrops or highest occurrences of float of the Raccoon. The approximate position of the base may be estimated by projecting the upper surface of the Sunbury shale, with allowance for the regional dip, eastward from the Lithopolis area where it is exposed.

On the east side of Chestnut Ridge, along the road running southeast from Jefferson and the farm lane in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ of section 3, Bloom Township, a thickness which probably lies somewhere between 130 and 160 feet is indicated.

On the west side of Chestnut Ridge, in a ravine located in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 9, Bloom Township, the upper contact of the Raccoon lies between 950 and 975 feet above sea level and a thickness on the order of 125 to 150 feet is indicated for the member.

Approximately half a mile to the north, in a ravine in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 9, Bloom Township, the approximate elevation of the Black Hand-Raccoon contact is 905 feet above sea level. Allowance for the regional dip indicates a probable thickness of about 80 feet for the Raccoon.

The quality of the exposures prevents a determination of the reason for the variable thickness of the Raccoon in northern Bloom Township. The variation suggests a disconformity separating the Raccoon and Black Hand. It is possible, however, that an intertonguing relationship rather than a disconformable one exists, and that the writer has placed the upper contact at the base of a Black Hand tongue penetrating the Raccoon member. The resulting thickness for the Raccoon would then be less than the true thickness of the member.

Approximately 12 miles southwest of Chestnut Ridge, in south-central Hocking Township, thicknesses of 120 and 138 feet have been recorded in wells which penetrated the Raccoon where it lies beneath the Hocking Valley tongue of the Black Hand member (p. 41). Hyde (1953, p. 107) noted a thickness of 198 feet for shales occurring at the base of the Cuyahoga formation near Mt. Pleasant in Lancaster.

East of the Hocking Valley the thickness of the Raccoon member increases where it is present as the lateral equivalent of the Black Hand member. Cuttings from an oil well (O. G. S. sample No. 676) in section 6, Jackson Township, Perry County, suggest that the total thickness of the Sunbury shale and Cuyahoga formation is 495 feet. The Sunbury is indistinguishable from the Raccoon, and the latter probably comprises the entire thickness of the Cuyahoga formation in this locality. A thickness of approximately 450 feet seems likely.

Cuttings from a second well (O. G. S. sample No. 775) in section 15, Walnut Township, indicate a thickness of at least 482 feet for the Cuyahoga formation. The actual thickness of the formation is undoubtedly somewhat greater, but the uppermost portion has been removed by erosion. The upper 147 feet of the formation at this locality consists mainly of very fine grained sandstone. If these beds are included in the Raccoon, a thickness in excess of 482 feet is indicated for the member. Some doubt exists, however, about whether or not the sandstone should be included in the Raccoon. It may represent the transition between the Raccoon member and a somewhat doubtful body of Black Hand sandstone lying to the southeast (p. 46). Exclusion of these beds from the Raccoon results in a thickness of about 335 feet for the member at this locality.

Considerable variation occurs in the thicknesses reported for the Raccoon by well drillers in eastern Fairfield County. In a few instances, thicknesses in excess of 500 feet have been noted. The greatest thickness recorded is 547 feet in a well in section 25, Pleasant Township. The accuracy of thicknesses based on drillers' logs, however, is questionable.

In southwestern Fairfield County, the approximate thickness of the Raccoon member may be inferred from scattered outcrops. An exposed thickness of 52 feet was noted in a measured stratigraphic section (O. G. S. 14546) in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ of section 34, Clear Creek Township, along the west bank of Salt Creek. Intermittent outcrops along Salt Creek for a distance of about a mile and a half to the north suggest a thickness of at least 110 feet for the Raccoon. About a mile east of Tarlton a small exposure of soft shale with thin intercalated fine-grained sandstone beds occurs in the ditch along the county road. The elevation of this exposure, estimated from the topographic map, is about 190 feet higher than the base of the southernmost outcrop on Salt Creek, a mile and a half to the west. Correction for the regional dip yields a thickness of at least 220 feet for the stratigraphic interval bounded by the two outcrops. A mile or more northeast of Tarlton, in the southern portion of section 26, Clear Creek Township, fine-grained sandstone crops out. The lowest known exposure of the sandstone, located along the east-west road in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ of section 26, lies approximately 25 feet higher than the highest exposure of Raccoon a mile to the south. The sandstone is thought to be transitional between the Raccoon and the Black Hand, which lies above and to the east. It is denoted in this investigation as Cuyahoga formation, undifferentiated, and is included with neither the Black Hand nor the Raccoon. The strata occupying the 25-foot covered interval are unknown, so that the thickness of the Raccoon present above drainage in the Tarlton area is at least 220 feet and may be 245 feet or even more, depending upon the magnitude of the regional dip and the portion of the covered interval which is occupied by the Raccoon member.

Cuttings from a well (O. G. S. sample No. 438) located in section 20, Amanda Township, suggest that the fine-grained clastic rocks of the Raccoon extend down to the top of the Sunbury shale in southwestern Fairfield County. The base of the Raccoon in the Salt Creek area is below drainage, but the total thickness of the member in this area is undoubtedly at least 250 feet and may be as great as 300 feet or more.

Because of the nature of the outcrops, it cannot be shown conclusively that the entire interval of 250 feet or more is occupied solely by the Raccoon. A tongue or tongues of Black Hand sandstone thinning westward may occupy part of this interval, but there is no evidence of such an occurrence.

Stratigraphic Relations

Well records, as well as outcrops in Bloom Township, indicate that the Raccoon occurs at the base of the Cuyahoga formation wherever the Cuyahoga is present in Fairfield County. The contact with the underlying Sunbury shale is known to be exposed in only two outcrops.

In a ravine located immediately northeast of Lithopolis, in the NE$\frac{1}{4}$ of section 7, Bloom Township (O. G. S. 10591), the Raccoon member rests with sharp contact on the Sunbury shale. Thin argillaceous lenses of the same color as the basal mudstone of the Raccoon are abundant in the upper few inches of the Sunbury.

Approximately a mile to the south, in a ravine in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ of section 18, Bloom Township (O. G. S. 14573), the contact is also exposed. Here the gray mudstone at the base of the Raccoon appears to grade downward into the black shale of the Sunbury in a transition zone 1 to 2 inches in thickness.

In much of central and western Fairfield County all but the lowest 80 to 160 feet of the Raccoon is replaced by the Hocking Valley tongue of the Black Hand member. The extent of the tongue is shown in figure 22. East of the Hocking Valley the Raccoon thickens markedly as it rises to occupy the stratigraphic position of the Black Hand (fig. 4). The change of facies is brought about by intertonguing between the Black Hand and Raccoon. This relationship is shown at several localities in the Hocking Valley and is discussed in detail later in this report (p. 56-62).

A layer of massive Black Hand sandstone can be traced over much of eastern Berne Township before it passes below drainage. It merges with the upper part of the main Hocking Valley tongue west of the Hocking River and separates the Raccoon from the overlying Logan formation throughout eastern Berne Township. In most of the localities where the base of the massive sandstone is exposed it is underlain by bedded, fine-grained sandstone (Cuyahoga formation, undifferentiated) which grades downward into the Raccoon. The eastward extent of the Black Hand is unknown because the member passes below drainage. Subsurface data from a well (O. G. S. sample No. 676) located in section 6, Jackson Township, Perry County, indicate that the Black Hand has disappeared completely, and the Raccoon is immediately overlain by the Logan formation. It is possible that the Raccoon comprises the entire thickness of the Cuyahoga formation in much of eastern Fairfield County.

West of the Hocking Valley tongue, in southern Clear Creek Township, the thickness of the Raccoon member increases to at least 250 feet and probably as much as 300 feet. Outcrops in this part of the county are scattered and generally small, and subsurface data are almost nonexistent. Therefore, little is known in western Fairfield County about the lateral relations of the Black Hand and Raccoon except that portions of the two members seem to occupy the same stratigraphic interval. Better exposures to the south in Hocking County have led workers in that area (Hohler, 1950; Hall, 1951, p. 31; and Hyde, 1953, p. 108-110) to the conclusion that the two members are facies equivalents, grading into and intertonguing with each other.

Outcrops in southwestern Amanda Township indicate that thin- to medium-bedded sandstone, which is predominantly fine grained, overlies the Raccoon in southwestern Fairfield County. The fine-grained sandstone is regarded as transitional between the Black Hand and Raccoon members and is denoted as Cuyahoga formation, undifferentiated.

The change of facies from Black Hand to Raccoon is shown west of Lancaster where the Raccoon is present between the two northern lobes of the Hocking Valley tongue. Exposures in this area are so poor that little is known except that the Raccoon member is present and a change of facies has occurred.

Thin mudstone alternating with thin beds of fine-grained sandstone occurs in the ravine immediately west of Jacobs Ladder in the NE$\frac{1}{4}$ of section 34, Hocking Township (O. G. S. 14594). Hyde (1953, p. 117) reported the occurrence of 100 feet of shale occupying a similar stratigraphic position in a well drilled in the SW$\frac{1}{4}$ of section 35, Hocking Township. Approximately 2 miles to the south in section 12, Madison Township (O. G. S. 14597), thin shales occur within the Black Hand in approximately the same stratigraphic position. These strata probably represent a tongue or tongues of Raccoon penetrating the Black Hand sandstone. Sufficient data to determine the origin of the tongues are not available.

Age

Except where the Black Hand member is present, the Raccoon member constitutes most or all of the thickness of the Cuyahoga formation. Its age, therefore, is the same as that of the Cuyahoga, possibly late Kinderhook and early Osage (p. 30-32). Wherever the Raccoon is exposed in the county it lies stratigraphically below the highest beds of the Black Hand member and is, therefore, somewhat older than the uppermost portion of the Black Hand.

The position of the Kinderhook-Osage boundary is presently unknown. Little attempt at correlation on either a regional basis or a local basis has been made so far.

Black Hand Member

Definition

L. E. Hicks (1878, p. 216, 217) used the name "Black Hand conglomerate" in referring to 85 to 90 feet of coarse-grained sandstone and conglomerate lying above the Raccoon shales and below the Licking shales (Logan formation) in the gorge of the Licking River near Hanover, Licking County. The U. S. Geological Survey regards the Black Hand as a distinct formation overlying the Cuyahoga formation and underlying the Logan formation.

In 1915 Hyde redefined the Black Hand, reducing it from formational rank to the status of a member of the Cuyahoga formation. He distinguished the upper few feet as the Berne member, which he later assigned to the overlying Logan formation (Hyde, 1921, p. 152-154). He (Hyde, 1915, p. 657) noted that the Black Hand overlies the Raccoon shales in central Licking County and the Fairfield member in central Fairfield County. The writer has found that strata fitting Hyde's (1915, p. 671, 672) definition of the Fairfield member are exposed only in a small area lying immediately west of the Hocking Valley. Here the coarse-grained sandstone facies and shale facies of the Cuyahoga formation intertongue. The beds of the shale facies (Raccoon member of this report) can be shown to wedge out to the west into a massive body of sandstone in which Hyde's Fairfield and Black Hand members are indistinguishable. The writer prefers to use the term "Black Hand member" to refer to the entire thickness of the coarse sandstone and conglomerate facies of the Cuyahoga formation wherever it is present. In Fairfield County the Raccoon member is regarded as both subjacent and laterally equivalent to the Black Hand. Locally, a variable thickness of thin- to medium-bedded, fine-grained sandstone, denoted as Cuyahoga formation, undifferentiated, separates the Black Hand and Raccoon members.

Distribution

The Black Hand member occurs as an elongate north-northwest-trending body of sandstone occupying much of central and western Fairfield County. The approximate areal distribution of the sandstone body, denoted as the Hocking Valley tongue in order to distinguish it from similar bodies of Black Hand sandstone elsewhere in Ohio, is shown in figure 22.

The Hocking Valley tongue extends north from Hocking County and underlies most of Madison, Berne, and Hocking Townships. In north-central Hocking Township it bifurcates, forming two northwest-trending lobes. The more easterly lobe, which is spectacularly exposed at Mt. Pleasant, passes north through Lancaster. Its northernmost exposures lie about a mile south and southwest of Dumontville in east-central Greenfield Township. The second lobe can be traced by means of intermittent exposures in the line of hills extending from northwestern Hocking Township to Chestnut Ridge in north-central Bloom Township.

The easternmost exposures of the Black Hand occur in eastern Berne Township, where the member, greatly thinned, forms prominent cliffs. The eastward extent of the member is unknown because it passes below drainage in eastern Berne Township, but stratigraphic considerations and scanty subsurface data suggest that it is probably absent in eastern Fairfield County.

A small lobe of Black Hand sandstone lying in Marion and Falls Townships, Hocking County, has been noted by Hyde (1915, p. 675; 1953, p. 94-98) and Merrill (1950, p. 77, 78, and pl. 8). The lobe passes below drainage in northern Marion Township, but there is some rather questionable evidence which indicates that it may continue to the north in the subsurface of Fairfield County. Drillers' logs from a number of wells in Rush Creek and Richland Townships report the occurrence of 20 to 245 feet of sand, usually denoted as Injun or Big Injun, lying from 300 to almost 500 feet above the base of the Cuyahoga formation. No information is available on the lithologic character of these strata, and the thicknesses reported vary erratically. The Injun sand in these wells may represent a body of Black Hand sandstone in eastern Fairfield County. On the other hand, the sand may be much too fine to be considered Black Hand and may represent a transition from the coarse sandstone of the Black Hand, which is exposed in Marion Township, to the very fine grained clastic rocks of the Raccoon member. It is also possible that some of the very fine grained sandstone which normally occurs in the Raccoon has been denoted as Injun by the drillers where it occurs in the interval occupied by the Big Injun in eastern Ohio. Cuttings from a well (O. G. S. sample No. 676) located just east of Rush Creek Township in section 6, Jackson Township, Perry County, indicate that the Cuyahoga at that locality contains nothing coarser than siltstone to very fine grained sandstone.

The Injun sand has been reported in only a few of many wells located in sections 14 and 23, Walnut Township. Cuttings from a nearby well (O. G. S. sample No. 775) located in section 15 show that very fine grained sandstone predominates in the upper part of the Cuyahoga formation. It may be inferred that either some drillers have denoted very fine grained sandstone near the top of the Cuyahoga formation as Injun, or that this sandstone is transitional between the Raccoon and coarser strata found in wells to the east and southeast.

Lithologic Character

Merrill (1950, p. 71) noted that the Black Hand member in northern Hocking County has a tendency to consist of three parts: a lower, massive, pebbly unit which is ledge forming; a middle, bedded, less pebbly unit which is generally less well exposed; and an upper, massive, pebbly unit which is a ledge former.

Upper and lower divisions. - A similar type of division can be recognized in parts of Fairfield County, but no equivalence to the Hocking County divisions is implied. The Black Hand consists of an upper, massive, ledge-forming unit, which forms the scenic cliffs in the southern part of the county, and a lower, somewhat finer grained unit which shows some tendency toward the formation of bedding and is sometimes rather poorly exposed because of its poor resistance to weathering. The two units are not always distinct, and in some localities they are totally inseparable. Locally, as along the banks of Clear Creek in eastern Madison Township, the lower unit displays a well developed massive, ledge-forming habit and produces bold cliffs similar in appearance to those of the upper unit. Elsewhere, as in much of southeastern Madison Township, the upper unit loses its pronounced ledge-forming character, so that the distinction between the upper and lower units is questionable.

The lower unit can be recognized throughout much of the central and western portions of the Hocking Valley tongue, as well as in a few outcrops located north of Lancaster. West of the Hocking Valley, in southern Berne Township, its identity is lost as it approaches the zone of intertonguing between the Raccoon and Black Hand members. In this area, massive sandstone ledges, which closely resemble the ledges of the upper unit, occupy the position of that portion of the lower unit which has not passed below drainage.

The upper unit is readily recognized in that portion of the county where it forms prominent cliffs. It caps the hills north of Lancaster in southeastern Greenfield and southwestern Pleasant Townships and forms prominent cliffs in much of Hocking Township and almost all of Berne Township. Considerably thinned, it passes below drainage in eastern Berne Township. Its westernmost exposures occupy the highest hills in the vicinity of Delmount, in west-central Hocking Township, and at the hilltops in the SE$\frac{1}{4}$ of section 30, Madison Township. The greatest continually exposed thickness of the upper unit, where it is typically formed, is in the 90-foot vertical cliff at Jacobs Ladder in the NE$\frac{1}{4}$ of section 34, Hocking Township (O. G. S. 14594). In much of Madison Township its cliff-forming tendency is somewhat subdued so that it is less readily distinguished from the lower unit.

Color. - The color of the Black Hand ranges through a number of shades of yellow, orange, brown, red, olive, and gray. Of the 25 separate shades noted for the member, only 5 occur with any consistency. The most frequently noted color is dark yellowish orange (10 YR 6/6). Occurring almost as frequently is grayish orange (10 YR 7/4). Light brown (5 YR 5/6), moderate yellowish brown (10 YR 5/4), and moderate reddish brown (10 R 4/6) are fairly common. In some localities the red color seems to be a local phenomenon, occurring in small patches which grade into or occupy the same interval as non-reddish sandstone. In other localities it appears to be fairly persistent in the lower bedded portions. It seldom occurs in the upper cliff-forming portion of the Black Hand. The red color is particularly well shown in some of the exposures in southwestern Hocking Township, southeastern Bloom Township, and in the vicinity of Lancaster, in northeastern Hocking, southeastern Greenfield, and southwestern Pleasant Townships.

The reds, yellows, and browns of the Black Hand are caused by the presence of iron oxide either as a coating on the constituent sand grains or as an interstitial filling. Where the amount of iron oxide is relatively small, as in much of the upper unit of the member, the color tends more toward grayish orange (10 YR 7/4). On weathered surfaces the darker shades of gray commonly predominate.

Grain size and sorting. - In a general sense, one of the most distinctive features of the Black Hand member is the relatively great coarseness of its sediments. In detail, however, its grain size is extremely variable, ranging from clay to pebbles as large as 3 inches in diameter.

The lower unit in many places is poorly sorted. Grain sizes ranging from silt to pebbles are not uncommon in a single outcrop. Medium-grained sand is probably the most abundant constituent of the lower portion of the Black Hand, but a considerable amount of finer sediment is present almost everywhere, and coarser sand, granules, and pebbles occur in many places. The pebbles are usually smaller than a quarter of an inch in diameter, but pebbles as large as three-quarters of an inch in diameter have been noted. Coarse-grained sand does not occur commonly in discrete layers, but rather is usually mixed with finer grained sediments. Rapid gradation from fine- to medium-grained sandstone to fine- to coarse-grained sandstone is common. Granules and pebbles are sometimes randomly scattered throughout a portion of the rock. Elsewhere they occur as thin, distinct conglomerate layers or lenses.

Especially characteristic of the lower unit is the occurrence of fines, not only interstitially, but also in the form of clay galls and clay layers and lenses. The galls are flat and ovoid and consist of light gray, plastic clay. They range from a fraction of an inch to 5 inches in diameter, but most commonly the diameter is 1 to 2 inches. On exposed surfaces they weather out rapidly, leaving almond-shaped pits on the face of the outcrop. The clay galls are commonly randomly distributed with an orientation which is subparallel to the bedding. In some instances, however, they occur in great profusion with random orientation, forming "clay pebble conglomerates" (fig. 15), which generally occur in small distinct lenses.

Figure 15. - Boulder of "clay pebble conglomerate" from the lower part of the Black Hand member in section 7, Berne Township (O. G. S. 14590).

At their maximum development these lenses may be as much as 2 feet thick and several tens of feet in length. A good exposure is present on the west side of the small hill immediately south of Lancaster in section 7, Berne Township (O. G. S. 14590).

Layers or lenses of light gray, plastic clay are also common in the lower unit. These generally range from a fraction of an inch to 6 inches in thickness and commonly contain a small amount of sand. Intermediate between clay layers and "clay pebble conglomerates" are sandy bodies of clay containing abundant fragments of sandstone.

In spite of the occurrence of abundant fine-grained detritus in the lower portion of the Black Hand, the occurrence of shale is not typical. Six feet of medium dark gray (N4) mudstone with thin intercalated fine-grained sandstone is exposed in a ravine tributary to Arney Run in section 34, Hocking Township (O. G. S. 14594). One foot of light gray (N6) shale with thin sandstone intercalations was noted in a ravine tributary to Clear Creek in section 12, Madison Township (O. G. S. 14597). The two outcrops resemble greatly the outcrops of the Raccoon member where it occurs in ravines immediately west of the Hocking River, and may represent thin tongues of Raccoon which have penetrated deep into the Hocking Valley tongue.

The upper portion of the Black Hand shows somewhat better sorting than the lower portion because material finer than medium-grained sand is generally much less abundant, although fines are abundant in a few localities. Medium- to coarse-grained sand occurs in the greatest quantity, but very coarse grained sand, granules, and pebbles are also abundant. The pebbles are usually a quarter of an inch or less in diameter, but pebbles with a diameter of an inch or more are locally common. A cobble 3 inches long was found in conglomeratic debris on top of the hill immediately south of Lancaster in the NW$\frac{1}{4}$ of section 7, Berne Township (O. G. S. 14590). Granules and pebbles are most abundant in the portion of the Hocking Valley tongue which lies west of the Hocking River and in the lobe of the Hocking Valley tongue which passes north through Lancaster. East of the Hocking River in Berne Township the Black Hand consists of medium- to coarse-grained, and in some places very coarse grained, sandstone. Granules and pebbles are present only in the southernmost part of this area.

The pebbles occur most frequently in conglomeratic layers or lenses which are parallel to the bedding. Streaks of pebbles frequently may be found along the sweeps of cross beds. In some localities conspicuous scours occur within the upper unit, and these are usually filled with conglomeratic sandstone containing pebbles up to an inch or more in diameter (fig. 16). This type of occurrence is well

Figure 16. - Scour in the Black Hand sandstone at Jacobs Ladder (O. G. S. 14594). Pole is marked in tenths of feet.

shown at the head of the ravine in the northeast corner of section 31, Berne Township (O. G. S. 14596), and on the south side of the cliff at Mt. Pleasant in Lancaster (O. G. S. 14567).

The absence of clay galls and clay lenses or layers is one of the criteria which may be used to distinguish the upper portion of the Black Hand from the lower portion. A few exceptions, however, are known. At the Sharp quarry in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ of section 9, Berne Township (T. 13 N.) (O. G. S. 14559), a few lenses of soft, blocky mudstone up to 6 feet in width may be seen in the quarry face. These weather to gray plastic clay and are unknown in the upper portion of the Black Hand elsewhere in the county. Abundant clay galls have been noted in section 24, Madison Township (O. G. S. 14600) in a bed of massive sandstone which forms a prominent ledge and, except for the clay galls, appears to be typical of the upper portion of the Black Hand member.

Composition. - The Black Hand sandstone is a relatively pure quartzose sandstone. Weathered feldspar and muscovite occur locally, especially in the finer grained portions of the member. The sand grains are generally subangular, although some of the coarsest sand and granules may be described as subrounded. The angularity is largely due to the growth of crystal faces by the secondary crystallization of quartz. Well-rounded pebbles, which usually consist of white quartz, are somewhat more abundant in the upper portion than in the lower portion. Merrill (1950, p. 72) also noted the occurrence of pebbles of smoky quartz, jasper, flint, chert, quartzite, and fine-grained sandstone, as well as weathered remains of carbonates, igneous and metamorphic rocks, and shale in the Black Hand of northern Hocking County.

Hydrous iron oxide occurs abundantly throughout most of the Black Hand member as interstitial fillings and coatings on sand grains. In some areas it also forms heavy crusts on bedding surfaces as well as irregular sinuous bands which show little relationship to the bedding. A hydrous iron oxide accumulation forms the floor of a small shelter known as the Summer House, on the south side of Mt. Pleasant in section 31, Pleasant Township (O. G. S. 14567). Here a bedding surface with well developed interference ripple marks, lying 44 feet below the top of the Black Hand member, and within the upper unit, has been excellently preserved because of the impregnation of the underlying sandstone by hydrous iron oxide to a depth of perhaps half an inch (fig. 17).

Figure 17. - Interference ripple marks preserved in a hydrous iron oxide layer in the Black Hand member at Mt. Pleasant in Lancaster (O. G. S. 14567). Brunton compass is alined north-south.

Sinuous bands of hydrous iron oxide, ranging in thickness from thin streaks the width of a pencil line to 2 inches or more, are present in much of the Black Hand member, but they are particularly abundant in the lower part. The bands are not discrete bodies of iron oxide, but rather they are merely sharply restricted portions of the sandstone in which hydrous iron oxide has become heavily concentrated.

Distinct bands of hydrous iron oxide are much less common in the upper ledge-forming portion of the Black Hand. Differential concentration of hydrous iron oxide is shown, however, by the typical formation of ferruginous nodes or of a pitted honeycomb pattern on weathered surfaces. Banding has been noted in a few localities west of the Hocking River in the upper portion of the Black Hand as well as in some of the lower tongues which wedge out into the Raccoon in the Hocking Valley area. It is rare or absent in eastern Berne Township. Especially notable is the occurrence at Riven Rock, located on the grounds of the Boys' Industrial School in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ of section 35, Hocking Township. On the cliff face the sandstone has largely weathered away so that the ferruginous bands stand out in a complex filigree (fig. 18).

Figure 18. - Filigree pattern shown by differential weathering of hydrous iron oxide bands in the Black Hand sandstone in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ of section 35, Hocking Township. Pole is marked in tenths of feet.

Bedding. - One of the major differences between the upper and lower units of the Black Hand member is the difference in bedding. The upper unit consists predominantly of massive sandstone which is crossbedded at many places. The lower unit, on the other hand, although massive in some outcrops, contains some distinctly bedded portions.

In a number of exposures of the lower unit thin- to medium-bedded sandstone occupies the same stratigraphic interval as massive sandstone. In two exposures the bedded sandstone can be seen passing laterally into or being truncated by massive sandstone. In the abandoned railroad cut in the NW$\frac{1}{4}$ of section 7, Berne Township (O. G. S. 14590), lateral gradation between massive and thin- to medium-bedded sandstone is common. In one instance, however, a massive sandstone ledge appears to truncate the laterally adjacent bedded sandstones (fig. 19). No significant

Figure 19. - Laterally adjacent bedded and massive Black Hand sandstone in section 7, Berne Township (O. G. S. 14590).

differences in grain size are apparent in the massive and bedded portions. A similar relationship is shown in a small shelter cave in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ of section 14, Madison Township. The shelter is located near the mouth of the first ravine east of the easternmost north-south road in section 14. Six feet of thin-bedded sandstone with clay layers and abundant clay galls near the top is replaced laterally and overlain by massive sandstone. Near the base the bedded sandstone appears to grade laterally into the massive portion, but in the middle and upper parts the massive sandstone sharply truncates the bedded sandstone. Both the massive and the bedded portions consist of fine- to medium-grained sandstone.

The reddish sandstones of the lower unit exposed southwest of Dumontville in eastern Greenfield Township and the sandstones exposed in the hills in western Hocking, northeastern Amanda, and eastern Bloom Townships commonly show poorly developed thin to medium bedding.

The conspicuous structures such as crossbedding, scours, and steep dips which characterize the upper portion of the Black Hand are largely absent or not recognized because of poor exposure in the lower portion. Crossbedding is shown in some exposures of the lower unit. In an outcrop at the 1166-foot crossroads in section 21, Hocking Township, the bedding shows an apparent dip of 11°, N. 15° E. Current ripple marks in the lower unit were seen in a single exposure, located along the east-west road in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 19, Greenfield Township. The ripple marks, present on only one bedding surface, were formed by north- to northeast-flowing currents.

In contrast to the partially bedded character of the lower portion, the upper part of the Black Hand member is massive. A rough stratification caused by variation in grain size and accentuated by differential weathering is developed in some parts of the area. Discrete layers bounded by bedding surfaces are not typical, but they are present in a few localities and commonly are associated with a much greater than normal variation in grain size.

The upper portion of the Black Hand is more distinctly crossbedded than the lower portion. The crossbedding is not conspicuous throughout the unit, but rather it seems to be a local phenomenon. Little uniformity is shown in the direction of dip of the cross beds; it is not unusual to find cross beds dipping in opposite directions in the same outcrop.

Steeply inclined beds which dip to the northeast are exposed in several outcrops of the upper portion of the Black Hand member in western Berne and eastern Hocking Townships (fig. 20). In a few localities true dips were measured and these range from 10° to 31° in directions ranging from N. 32° E. to N. 75° E. Dipping beds also occur in a road cut located about a mile south of Dumontville between sections 23 and 24, Greenfield Township (fig. 21). The average dip of the beds in

Figure 20. - Steeply inclined Black Hand sandstone in section 8, Berne Township (T. 13 N.) (O. G. S. 14602). Dip is 16°, N. 60° E. Horizontal beds in left center of photograph are truncated by the dipping beds.

Figure 21. - Dipping Black Hand sandstone in road cut on Ohio Route 158 about a mile south of Dumontville in Greenfield Township. Pole is 5 feet long and is approximately vertical. Average dip is 19°, N. 49° E.

this exposure is 19°, N. 49° E. Gentler dips were noted at Mt. Pleasant in Lancaster. Dips measured in the interval occurring 36 to 58 feet below the top of the Black Hand range from 3°, N. 20° E. to 6°, N. 65° E. In a few outcrops the dipping beds are overlain by horizontal beds which, according to Hyde (1915, p. 673), may be as thick as 25 feet. Where it is exposed, the upward decrease in inclination is gradual rather than abrupt.

The absence of markedly dipping beds over much of the outcrop area of the upper portion of the Black Hand suggests that the dip may be a local phenomenon rather than a truly distinguishing feature of the Black Hand. That it is depositional rather than tectonic in origin is indicated by its absence in both the subjacent and superjacent strata in the few sections where they are exposed together with the dipping beds of the Black Hand member. Because of the effects of regional dip, differential compaction, and slumping, the dips measured in the Black Hand may be somewhat greater now than they were initially.

Shelter caves. - A striking feature of the Black Hand member in Fairfield County results from the formation of small shelter caves in many localities. The shelters occur along the walls or at the heads of many steep ravines, and a few occur at present stream levels. They are present only in those portions of the Black Hand which tend to be ledge forming. Although most of the shelters are above the levels of the present streams, it seems likely that most are the result of stream erosion of relatively less resistant portions of the Black Hand, causing the removal of support and subsequent collapse of the superjacent ledge-forming rocks.

Shelter caves are especially well formed in the vicinity of Clear Creek in eastern Madison Township. Here the lower portion of the Black Hand shows a prominent ledge-forming habit. In the second ravine east of the easternmost north-south road in section 14, Madison Township, on the south bank of Clear Creek, the ledge-forming sandstones are well exposed. They are present at the mouth of the ravine and may be followed with little interruption up the ravine through a vertical interval of about 100 feet. Near the mouth of the ravine a shelter cave is presently being formed at stream level in the west bank. The walls and roof of the shelter consist of relatively hard, massive sandstones. Immediately above the floor of the shelter, however, is a zone of soft sandstone with abundant clay galls. The stream was dry when observed by the writer, but it was apparent that during flood, part of the stream flowed across the floor of the shelter, cutting an incipient meander where it eroded the less resistant rock above the shelter floor. The removal of the less resistant sandstone has resulted in partial collapse of the overlying more resistant sandstone, fragments of which litter the floor.

Shelter caves occur in the upper portion of the Black Hand in a number of localities both east and west of the Hocking River in Berne Township. In many places the underlying strata are covered, and the reason for cave formation is not apparent. In some instances, however, the shelter caves are formed at the contact between the Black Hand and Raccoon members or between the Black Hand sandstone and the underlying less resistant sandstone denoted as Cuyahoga formation, undifferentiated.

Thickness

Because of the facies relationship which exists between the Black Hand and Raccoon members, the thickness of the Black Hand is extremely variable. The greatest thicknesses occur along the axis of the Hocking Valley tongue and in its extension through Lancaster. To the east and west the thickness decreases rapidly because of the change of facies. The thickness of the Black Hand in the western portion of the Hocking Valley tongue also has been diminished by the erosion of the upper portion of the member.

The greatest thickness of almost continuously exposed Black Hand sandstone occurs south of Brushy Fork in the SW$\frac{1}{4}$ of section 9, Berne Township (T. 13 N.) (O. G. S. 14595). On the south wall of the valley, 240 feet of sandstone is exposed with little interruption from stream level to the base of the Logan formation. The only covered interval of significant thickness occurs within the uppermost 50 feet; its stratigraphic position is such that little doubt exists that it is underlain by typical Black Hand sandstone.

The Black Hand sandstone is exposed at the level of Clear Creek in eastern Madison Township at an elevation of about 800 feet above sea level. The contact between the Black Hand and the overlying Logan formation is exposed on the ridge south of Clear Creek in the SE$\frac{1}{4}$ of section 23, Madison Township (O. G. S. 14563), at an elevation of 1170 feet above sea level. Although part of the interval between Clear Creek and the base of the Logan is covered, a thickness of approximately 370 feet is indicated for that portion of the Black Hand member which lies above drainage.

Drillers' records (p. 41) from two wells located less than a mile south and southwest of Hamburg indicate that the base of the Black Hand lies close to 700 feet above sea level in south-central Hocking Township. (Well records and locations were obtained from the files of the Ohio Division of Geological Survey, and elevations were estimated from the topographic map.) The upper part of the Black Hand and the overlying Logan formation are absent due to erosion in the immediate vicinity of the wells, but projection of the base of the Logan formation from nearby outcrops results in a thickness of at least 500 feet for the Black Hand.

A similar thickness has been determined for the sandstones of the Cuyahoga formation at the Boys' Industrial School in the SW$\frac{1}{4}$ of section 36, Hocking Township. Hyde (1953, p. 117), using both outcrop and well data, showed that the interval between the lowest known sandstone of the Cuyahoga formation and the base of the Logan formation is 500 feet. Here, however, a 100-foot layer of shale occurs in the interval lying from 242 to 342 feet above the base of the sandstone.

At Chestnut Ridge in northern Bloom Township, the thickness of the Black Hand member is difficult to determine because of inadequate exposure. In a small ravine in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 9, Bloom Township, the base of the Black Hand is covered, but it is estimated to lie at about 905 feet above sea level. According to the topographic map, the highest point on the ridge, in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 10, is a little higher than 1110 feet above sea level. A thickness of slightly more than 200 feet is indicated. In the ravine just west of the road intersection in the center of the SE$\frac{1}{4}$ of section 9, Bloom Township, the Raccoon is well exposed at 950 feet above sea level, and the lowest outcrop of the Black Hand lies at about 975 feet above sea level. Scattered Raccoon float occurs in the covered interval. Here a thickness of no more than 160 feet and perhaps as little as 135 feet is indicated. It is not known how much of the upper part of the Black Hand member has been removed by erosion.

At Mt. Pleasant (O. G. S. 14567), in the eastern extension of the Hocking Valley tongue, 222 feet of Black Hand sandstone is exposed below the base of the Logan formation. Hyde (1953, p. 107), in a compilation of surface and subsurface data determined a total thickness of 412 feet of sandstone.

The Black Hand member is considerably thinner where it overlies the Raccoon member in Berne Township. Thicknesses as great as 90 feet occur west of the Hocking Valley in southern Berne Township. Eastward the Black Hand thins markedly. In the NE$\frac{1}{4}$ NW$\frac{1}{4}$ of section 27, Berne Township (O. G. S. 14564), the total thickness of the member is 20 feet. Farther east, below drainage, it probably wedges out completely into the Raccoon member.

Poor exposure, as well as removal of much of the member by erosion, prohibits precise determination of the thickness of the Black Hand in southwestern Fairfield County. The increased thickness of the Raccoon in Clear Creek Township, however, indicates that the Black Hand must be considerably thinner west of the axis of the Hocking Valley tongue.

Stratigraphic Relations

The Black Hand member is overlain with probable slight disconformity by the Logan formation and overlies the Raccoon member or, in some places, a variable thickness of transition beds (Cuyahoga formation, undifferentiated) which separate it from the Raccoon.

The Black Hand sandstone in Fairfield County constitutes the northern portion of the Hocking Valley tongue of the Black Hand member. The use of the term "Hocking Valley tongue" and the relationship of the tongue to occurrences of the Black Hand elsewhere in Ohio have been discussed previously in this paper (p. 26-30).

Subdivisions of the Hocking Valley tongue. - Several subdivisions of the Hocking Valley tongue may be recognized in Fairfield County (fig. 22). A prolongation of the Black Hand extends northwest from central Hocking Township to Chestnut Ridge in north-central Bloom Township. A second prolongation extends 3 to 4 miles north of Lancaster and is excellently exposed at Mt. Pleasant in southwestern Pleasant Township. A third prolongation of the Hocking Valley tongue occurs as a massive layer of sandstone which forms prominent ledges in the vicinity of Sugargrove and throughout much of the rest of Berne Township. It thickens westward and merges with the upper part of the main mass of the Hocking Valley tongue west of the Hocking River (fig. 4).

According to the accepted stratigraphic nomenclature for such bodies of sedimentary rock, the three subdivisions are tongues of the Hocking Valley tongue. The writer feels, however, that the use of the term "tongue" in describing subdivisions of a larger body which is also a tongue may obscure the subordinate relationship of the smaller bodies to the larger body and lead to confusion. It is therefore suggested that the term "lobe" be used to describe tongue-like prolongations of larger bodies which have been recognized as tongues. Accordingly, the three large prolongations of the Hocking Valley tongue which have been recognized in Fairfield County are denoted as lobes and, for the sake of convenience, are named for localities in which they are conspicuously exposed. They are, respectively, the Bloom, Pleasant, and Sugargrove lobes of the Hocking Valley tongue. Other lobes of the Hocking Valley tongue have been recognized in a few localities. Their exposures are of very limited areal extent, and they are not assigned formal stratigraphic names.

Position and nature of the Black Hand - Raccoon contact. - Throughout much of the county the base of the Hocking Valley tongue lies far below drainage. It rises above drainage, however, in the Bloom lobe in northern Bloom Township near Chestnut Ridge. Although the contact with the underlying Raccoon shale is not exposed, its apparent elevation varies enough to suggest marked disconformity. The estimated thickness of the underlying Raccoon ranges from a minimum of 80 feet to at least 130 feet and perhaps as much as 160 feet. The variability of the contact may indicate an intertonguing relationship rather than a disconformable one. If this is the case, the writer may have mistakenly placed the base of the Black Hand member within the zone of intertonguing rather than at the true base of the Black Hand.

In western Berne Township the Black Hand and Raccoon members intertongue. A massive lobe of Black Hand sandstone, the Sugargrove lobe, overlies the Raccoon in much of Berne Township. It thickens westward to at least 90 feet and merges with the upper part of the Hocking Valley tongue in western Berne Township. Thinning rapidly toward the east, it passes below drainage in eastern Berne Township with its identity still intact. Its absence in well cuttings in western Perry County (O. G. S. sample No. 676) indicates that it disappears in the subsurface in eastern Fairfield County.

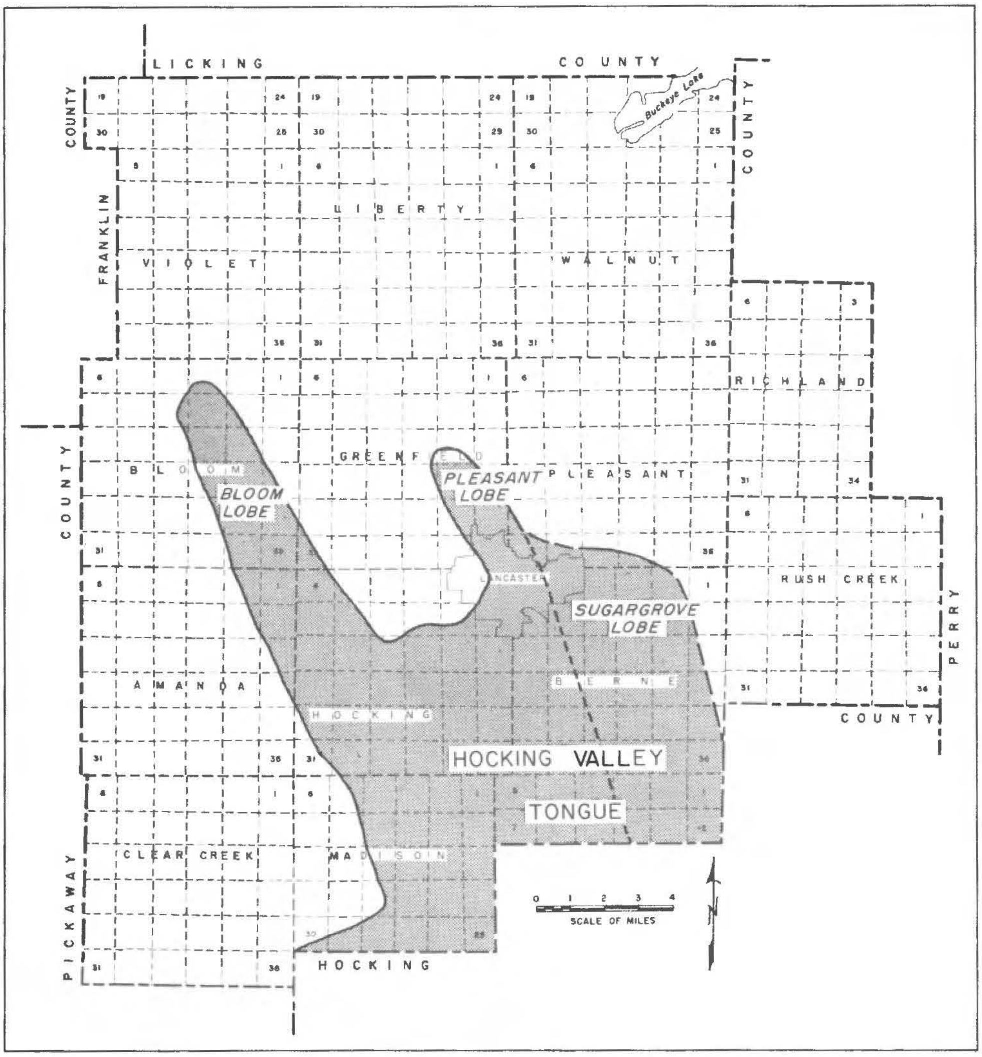


Figure 22. - Generalized distribution and subdivisions of the Black Hand sandstone in Fairfield County.

The Sugargrove lobe rests on thin- to medium-bedded, fine-grained sandstone (Cuyahoga formation, undifferentiated), which grades downward into the finer grained clastic rocks of the Raccoon member. The contact between the Black Hand and the underlying strata is generally covered by talus. It is exposed, however, south of Sugargrove in the NE$\frac{1}{4}$ of section 10, Berne Township (T. 13 N.) (O. G. S. 14550). The upward increase in grain size and loss of bedding is abrupt. The approximate position of the contact is well marked by a pronounced break in slope with steeper declivity developed where the Black Hand is present. Small shelter caves also occur at the base of the Black Hand. Unfortunately the exposures are inadequate for determining whether the contact is conformable or disconformable.

A stratigraphic section (O. G. S. 14570) measured along the Wheeling Road on the west wall of the valley of Pleasant Run in section 33, Pleasant Township, shows a sequence of strata which may mark the lateral transition between the Black Hand and Raccoon members. Approximately 19 feet of strata at the base of the section is considered to belong to the Cuyahoga formation. This consists of alternating mudstone, siltstone, bedded sandstone, and massive sandstone, each slightly greater than 4 feet thick. The upper one composes the uppermost unit thought to belong to the Cuyahoga formation; the lower one occurs just above the base of the section. The intervening units range in thickness from slightly less than 1 foot to slightly more than 2 feet. With the exception of the lower ledge-forming sandstone, no sand coarser than medium grained is present. The lower massive sandstone contains sand ranging in size from fine to coarse grained. Approximately three-quarters of a mile to the south in the northern part of section 4, Berne Township, the typical massive Black Hand sandstone of the Sugargrove lobe caps the hilltops at about the same elevation as the beds described above.

Field evidence for intertonguing relations of the Black Hand - Raccoon contact. - The intertonguing of the Black Hand sandstone and the finer grained clastic rocks of the Raccoon to the east is shown in several outcrops which lie west of the Hocking River, between Clear Creek in northern Hocking County and the prominent spur north of Blue Valley in southwestern Berne Township.

A stratigraphic section (O. G. S. 14549) was measured in a nearly completed road cut along the west wall of the Hocking Valley in the NW$\frac{1}{4}$ of section 15, Good Hope Township, Hocking County (fig. 23). Here the Black Hand sandstone overlies 112 feet of strata belonging to the Raccoon member and Cuyahoga formation, undifferentiated. This exposure of the Black Hand represents a portion of the Sugargrove lobe. At the base of the road cut the Black Hand sandstone is exposed as a lens 500 feet long. It is 8 feet thick near the center and thins north and south to a feather edge. It is in sharp contact with enclosing strata of the Raccoon member and is regarded as the distal end of a lower lobe of Black Hand sandstone.

Less than half a mile to the south a lobe of Black Hand sandstone is exposed at the base of the north wall of Clear Creek Valley where that valley opens into the Hocking Valley. The top of the lower sandstone, where it is exposed at the mouth of Clear Creek, lies 120 feet below the base of the upper sandstone (Hyde, 1953, p. 105). The top of the lower lobe rises rapidly to the west along the north wall of Clear Creek Valley. According to Hyde (1953, p. 104), the thickness of the lower sandstone increases to at least 100 feet within half a mile to the west of the mouth of Clear Creek. The interval between the upper and lower sandstone lobes, which is occupied by the Cuyahoga formation, undifferentiated, and the Raccoon member, diminishes accordingly. A 240-foot sequence of Black Hand sandstone, with no intervening shales, located in the SW$\frac{1}{4}$ of section 9, Berne Township (T. 13 N.) (O. G. S. 14595), indicates that the fine-grained clastic rocks of the Cuyahoga wedge out rapidly to the west in the Hocking Valley tongue.

Figure 23. - Intertonguing Black Hand and Raccoon members in road cut on U. S. Route 33 just south of the Fairfield-Hocking County line (O. G. S. 14549). Black Hand occurs as ledges at base of outcrop and caps the hilltop. Intervening beds (Raccoon member and Cuyahoga formation, undifferentiated) wedge out to the west.

An exposure located near the head of the second ravine west of the Hocking Valley on the north side of Clear Creek in the NE$\frac{1}{4}$ of section 16, Good Hope Township, Hocking County (O. G. S. 14601), displays clearly the intertonguing of the Raccoon and Black Hand members. The lower 50 feet of the Sugargrove lobe of the Black Hand member is excellently exposed where it forms a prominent shelter cave 100 to 150 feet wide. Eight feet of typical Raccoon siltstone and shale is exposed in the stream bank below the shelter. A 16-foot covered interval separates this outcrop from the lowest exposures in the walls of the shelter. In the southwest portion of the shelter, which is alined from southwest to northeast across the ravine, a medium gray (N6), silty, micaceous, soft mudstone, ranging in thickness from 2.0 to 6.5 feet can be seen. It is buried by debris in the central and northeast portions of the shelter. The massive Black Hand sandstone rests on the mudstone with a sharp and markedly undulatory contact. A little more than 3 feet above the base of the Black Hand is a bed of very light gray (N5), sandy, soft, plastic clay which has a maximum thickness of slightly over half a foot. It rests on the Black Hand with sharp contact and is overlain by the Black Hand with a sharp and slightly undulatory contact. It can be traced across the central and northeast portions of the shelter wall, but near the southwest end of the shelter it thins and wedges out into the Black Hand sandstone. It seems likely that the mudstone exposed at the base of the shelter in its southwestern portion, as well as the siltstone and shale exposed below in the banks of the ravine, is continuous with the Raccoon member exposed in the road cut (O. G. S. 14549) half a mile to the east, on the west wall of the Hocking Valley. The fine-grained sandstone (Cuyahoga formation, undifferentiated) which separates the Raccoon from the Black Hand along the Hocking Valley is absent at the shelter, and the Black Hand rests with sharp and perhaps disconformable contact on the Raccoon member. The lower sandstone, which merges to the southwest with the thick, upper body of sandstone, and the thin clay bed, which wedges out into sandstone to the southwest, probably represent local intertonguing between the Black Hand and Raccoon members.

The intertonguing of the Raccoon and Black Hand on the east flank of the Hocking Valley tongue also may be inferred from a series of exposures on the north wall of Blue Valley in the southwestern part of Berne Township. The easternmost of these exposures is in a new road cut (O. G. S. 14547) on the west wall of the Hocking Valley at the eastern tip of the prominent spur which forms the north wall of Blue Valley. At the base of the cut is 67 feet of interbedded mudstone and siltstone belonging to the Raccoon member, overlain by 26 feet of fine-grained, medium-bedded sandstone denoted as Cuyahoga formation, undifferentiated. Overlying the bedded sandstone, and separated from it by a covered interval approximately 3 feet thick, is slightly more than 50 feet of typical, massive, coarse-grained Black Hand sandstone. It is easily traced westward along the spur because it forms prominent cliffs as much as 75 feet high. About a mile west of the road cut, fragments of the overlying Logan formation occur in the debris of a pipeline trench which crosses the ridge top in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 32, Berne Township.

Nature of facies change between Black Hand sandstone and Raccoon shale. - A little more than a mile to the southwest of the road cut, the Blue Valley road intersects a southeast-trending spur of the north wall of Blue Valley at Blue Valley School near the center of section 32, Berne Township. A stratigraphic section (O. G. S. 14606) measured along the spur shows a lower unit consisting of 12 feet of Black Hand sandstone and an upper unit consisting of 65 feet of Black Hand sandstone. The two outcrops of Black Hand sandstone are separated by a covered interval 135 feet thick. Fragments of hard, very fine grained to fine-grained sandstone and a few fragments of shale occur in the covered interval. The lower sandstone thickens rapidly to the west. At Blue Valley School the elevation of its upper surface is 812 feet above sea level. About half a mile to the west, just east of the 810-foot crossroads, the highest exposure of the lower sandstone lies almost 880 feet above sea level, and its thickness has increased from 12 to at least 75 feet. Half a mile along the road northwest of the 810-foot crossroads the top of the sandstone is at least as high as 934 feet above sea level; the lower portion is covered in this outcrop so that the exposed portion of the sandstone is only 84 feet thick. Almost a mile to the northwest, along the same road in the NE$\frac{1}{4}$ of section 36, Hocking Township, more than 100 feet of Black Hand sandstone is overlain by the Logan formation (O. G. S. 14562). The lowest exposure of sandstone at this locality lies at an elevation of 980 feet above sea level.

The upper sandstone exposed north of Blue Valley School, as well as the sandstone which caps the road cut to the east, lies in the proximal portion of the Sugargrove lobe. The lower sandstone, which is exposed along Blue Valley road, is a lower lobe occupying a stratigraphic position similar to that occupied by the lower lobe near the mouth of Clear Creek. Because of the rapid westward thickening of the lower lobe, it seems certain that the upper and lower sandstones must coalesce west of Blue Valley School.

Six feet of interbedded mudstone and fine-grained sandstone are exposed approximately 200 feet below the top of the Cuyahoga formation in the ravine immediately west of Jacobs Ladder in the NE$\frac{1}{4}$ of section 34, Hocking Township (O. G. S. 14594). Similar beds, associated with fine-grained, thin-bedded sandstones containing abundant clay galls also are exposed about 200 feet below the top of the Cuyahoga formation in the SE$\frac{1}{4}$ of section 12, Madison Township (O. G. S. 14597). Both outcrops may represent a tongue or tongues of the Raccoon member. The present data are insufficient for determination of their origins.

A few scattered outcrops between the Bloom and Pleasant lobes of the Hocking Valley tongue indicate that the Raccoon is present in north-central Hocking Township and southern Greenfield Township, but little is known about the nature of the facies change.

Thirteen feet of fine- to medium-grained, medium-bedded sandstone overlies Black Hand sandstone (fig. 25) on the northeast side of the small hill in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 36, Greenfield Township (O. G. S. 14587), and 55 feet of similar sandstone is exposed approximately three-quarters of a mile to the northwest on the small hill in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 36, Greenfield Township. These strata, classified as Cuyahoga formation, undifferentiated, lie on the west flank of the Pleasant lobe and probably represent a transition from the coarse-grained, massive sandstone found at Mt. Pleasant to the fine-grained, bedded rocks of the Raccoon, which are exposed within 2 miles to the south and west.

It is not known whether or not the Raccoon in the "embayment" was ever entirely overlain by the Black Hand member. However, an exposure of more than 100 feet of typical Black Hand sandstone at Beck's Knob in the SW$\frac{1}{4}$ of section 10, Hocking Township, suggests that the area between the two northern lobes may have been overlain, at least in part, by the Black Hand. If so, either the Black Hand has been completely removed by erosion, or any remnants of it are concealed by glacial drift.

The eastern limit of the Pleasant lobe is well defined by many exposures of the Raccoon member along the valley walls of Ewing and Fetters Runs in southwestern Pleasant Township. Alternating massive and thin-bedded, medium-grained sandstones which suggest lateral transition are exposed in a road cut in the NE$\frac{1}{4}$ SE$\frac{1}{4}$ of section 29, Pleasant Township (fig. 24).

Figure 24. - Alternating massive and thin-bedded sandstone in the zone of facies change along the east edge of the Pleasant lobe in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ of section 29, Pleasant Township. Pole is 5 feet long.

Because of relatively poor exposure, the relationship between the Raccoon and Black Hand members on the west flank of the Hocking Valley tongue is not as well understood as it is along the eastern flank. In south-central and southeastern Clear Creek Township the estimated thickness of the Raccoon is at least 250 feet and may be considerably greater. The interval between the top of the Sunbury and the base of the Hocking Valley tongue of the Black Hand member is thought to be between 100 and 150 feet. The Raccoon member in Clear Creek Township must, therefore, occupy part of the interval occupied by the sandstones of the Hocking Valley tongue farther east, thus indicating a change in facies.

Whether the change of facies is brought about by lateral gradation or by sharply defined intertonguing is not known. There is some inconclusive evidence that lateral gradation rather than sharp intertonguing has brought about the facies change.

In the hills in section 10, Clear Creek Township, and in southwestern Amanda Township are scattered outcrops of thin- to medium-bedded, fine- to medium-grained sandstone denoted as Cuyahoga formation, undifferentiated. The sandstone is micaceous and argillaceous, and in one instance contains small, scattered clay galls. These beds lie within the stratigraphic interval of the Black Hand, which is exposed several miles to the east, and they are thought to represent a bedded, somewhat finer grained western facies equivalent of the Black Hand member. They may well be transitional between the typical massive, coarse-grained Black Hand sandstone found farther east and the finer grained strata of the Raccoon member.

A second type of evidence, negative in nature, suggests that the facies change on the western flank of the Hocking Valley tongue may be brought about by gradual transition rather than large-scale intertonguing. Along the eastern flank of the Hocking Valley tongue, where large-scale intertonguing is well displayed, the lobes of Black Hand sandstone retain their massive, ledge-forming character as they pass eastward into the fine-grained clastic rocks of the Raccoon member. It seems likely that if large, discrete lobes of Black Hand sandstone emanated from the western flank of the Hocking Valley tongue, as they do from the eastern flank, they might be expressed topographically by a rugged landscape characterized by steep sandstone ledges. Clear Creek Township and western Madison Township, however, are characterized by gently rolling topography in which outcrops are few and generally poor; the absence of large discrete bodies of massive Black Hand sandstone is suggested. It is entirely possible, however, that massive ledges of Black Hand, if present, are obscured by the terminal Wisconsin moraine.

A lobe of Black Hand sandstone once may have been present in the upper part of the Cuyahoga formation in some of the area west of the axial portion of the Hocking Valley tongue. Large blocks of typical Black Hand sandstone are found on the tops of the highest hills in the vicinity of the 1118-foot crossroads in section 30, Madison Township (O. G. S. 14571). The Black Hand in this locality is recognized as a lobe of the Hocking Valley tongue because of the exposure near the 1118-foot crossroads of fine-grained, thin- to medium-bedded sandstone (Cuyahoga formation, undifferentiated) lying stratigraphically below the Black Hand.

Age

The Cuyahoga formation is considered to be early Mississippian (Kinderhook and Osage) in age (p. 30-32). The position of the Kinderhook-Osage boundary in the Cuyahoga formation of Fairfield County is unknown. Because the Black Hand occupies all but the lowermost portion of the Cuyahoga formation in central and western Fairfield County, it is certainly of Osage age and may or may not be partially Kinderhook in age.

Cuyahoga Formation, Undifferentiated

Definition

Cuyahoga formation, undifferentiated, is the name used for a variable thickness of predominantly fine-grained, thin- to medium-bedded sandstone which occupies a stratigraphic position between the Black Hand and Raccoon members of the

Cuyahoga formation. A representative exposure occurs in a road cut on the west side of U. S. Route 33 north of Blue Valley in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ of section 28, Berne Township (O. G. S. 14547).

Because of infrequent exposure, these beds are mappable only on a very local basis. Their stratigraphic continuity cannot be demonstrated, and they may represent several discrete stratigraphic units of local extent. They are not considered to be equivalent to the Black Hand and Raccoon members in stratigraphic importance. The writer feels, however, that it is worthwhile to distinguish them from the Black Hand and Raccoon members. Therefore, the fine-grained, bedded sandstones are not accorded member status with a formal stratigraphic name, but rather they are denoted less formally as Cuyahoga formation, undifferentiated.

Distribution

The fine-grained sandstones of the Cuyahoga formation, undifferentiated, occur in the southern part of the county both east and west of the axis of the Hocking Valley tongue. On the west wall of the Hocking Valley they are exposed in the road cut in the NW$\frac{1}{4}$ of section 15, Good Hope Township (O. G. S. 14549), and in the road cut north of Blue Valley in sections 28 and 33, Berne Township (O. G. S. 14547). East of the Hocking Valley they usually may be seen in any section in which the base of the Black Hand member is exposed. The northernmost exposures occur in section 29, Pleasant Township, along the west valley wall of Ewing Run. Northwest of Lancaster the unit is exposed in section 36, Greenfield Township.

In the western part of the county, exposures of the Cuyahoga formation, undifferentiated, are known near the 1118-foot crossroads in section 30, Madison Township (O. G. S. 14571), in the hills in the southeastern and north-central portions of Clear Creek Township, and in southwestern Amanda Township.

Because of the tendency of the fine-grained sandstone to form slopes rather than ledges, and because it also is likely to be buried by talus from the overlying Black Hand member, the best exposures occur almost exclusively in road cuts.

Lithologic Character

The lithologic character of the Cuyahoga formation, undifferentiated, is remarkably uniform. The most frequently noted color is dark yellowish orange (10 YR 6/6). Other colors include grayish orange (10 YR 7/4), pale yellowish brown (10 YR 6/2), light brown (5 YR 5/6), and moderate yellowish brown (10 YR 5/4). In one exposure, the new road cut north of Blue Valley in western Berne Township (O. G. S. 14547), the color ranges from light gray (N7) to dark yellowish orange (10 YR 6/6). The sandstone in many areas is iron stained on the weathered surface, and in a few instances it contains thin, sinuous bands of hydrous iron oxide.

A diagnostic feature of the unit is the development of thin- to medium-bedded strata. Commonly the beds are hard and rather brittle, but in a few exposures they are rather soft. Ordinarily the constituent sand grains do not exceed the size of fine-grained sand. In an outcrop in the SE$\frac{1}{4}$ of section 16, Berne Township (O. G. S. 14582), however, a few scattered grains of subrounded, medium-grained sand occur. Some medium-grained sand and, in one instance, a few grains of coarse sand, are also present in the outcrops in northern Clear Creek, southwestern Amanda, and southeastern Greenfield Townships.

The sandstone is commonly micaceous. In the outcrop located in section 30, Madison Township (O. G. S. 14571), abundant fragments of weathered feldspar occur. Clay galls, usually less than an inch in diameter, but sometimes as large as 2 inches in diameter, occur in some localities. Scattered brachiopods and crinoid columnals occur on the bedding surfaces of float blocks found in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 4, Berne Township (O. G. S. 14568).

The Cuyahoga formation, undifferentiated, is distinguished from the underlying Raccoon member because it consists entirely of sandstone and contains no shale, mudstone, or siltstone. It is readily distinguished from the overlying Black Hand because of its well formed bedding and the relatively small size of its constituent grains.

Thickness

The base of the Cuyahoga formation, undifferentiated, is exposed in very few outcrops. The greatest known thickness occurs in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 36 Greenfield Township, where 55 feet of sandstone is exposed. The base is covered and the overlying beds have been removed by erosion.

Along the east wall of the Hocking Valley in the ravine located in the NE$\frac{1}{4}$ of section 10, Berne Township (T. 13 N.) (O. G. S. 14550), the unit is intermittently exposed. The lowest exposure lies almost 54 feet below the contact between the Black Hand and the Cuyahoga formation, undifferentiated. A 16-foot covered interval separates the lowest exposure of the Cuyahoga formation, undifferentiated, from the uppermost outcrop of the Raccoon member. The thickness, therefore, is between 54 and 70 feet.

About a mile and a half to the southwest, in the northeast quarter of section 16, Good Hope Township, Hocking County (O. G. S. 14601), the base of the Black Hand rests directly on the Raccoon member; the Cuyahoga formation, undifferentiated, is absent.

In the NW$\frac{1}{4}$ of section 27, Berne Township (O. G. S. 14564), the lowest exposed portion of the Cuyahoga formation, undifferentiated, lies 37 feet below the base of the Black Hand member. Approximately a mile to the southwest, in the road cut north of the mouth of Blue Valley (O. G. S. 14547), 26 feet of the unit is exposed. With allowance for a short covered interval at the base of the Black Hand member, the greatest possible thickness here is 29 feet. Within a distance of probably little more than 2 miles to the west this stratigraphic interval may be occupied by a continuous sequence of Black Hand sandstone. Undoubtedly the Cuyahoga formation, undifferentiated, thins and disappears near the margin of the Hocking Valley tongue.

No determination of thickness is possible in western Fairfield County. The greatest known thickness occurs in the SE$\frac{1}{4}$ of section 30, Madison Township (O. G. S. 14571), where 22 feet of the Cuyahoga formation, undifferentiated, is exposed. At this locality, however, the base of the unit is covered and the top is separated from the lowest outcrop of Black Hand sandstone by a covered interval of almost 20 feet.

Stratigraphic Relations

The contact between the Cuyahoga formation, undifferentiated, and the Raccoon member is exposed only in the new road cut on the west wall of the Hocking Valley half a mile north of Blue Valley (O. G. S. 14547). In this outcrop the contact is gradational. In the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 36, Greenfield Township (O. G. S. 14587), the Cuyahoga formation, undifferentiated, lies with sharp contact on massive Black Hand sandstone (fig. 25). The upper contact is exposed in the NE$\frac{1}{4}$ of section 10, Berne Township (T. 13 N.) (O. G. S. 14550). It appears to be abrupt, but there is no evidence of a disconformity.

The Cuyahoga formation, undifferentiated, is regarded as representing a transition, laterally as well as vertically, between the Raccoon member and the Sugargrove lobe of the Black Hand member, which is exposed over much of Berne Township. The sparse data pertaining to the thickness of the unit indicate that it

Figure 25. - Bedded sandstone (Cuyahoga formation, undifferentiated) resting on massive Black Hand sandstone on west flank of Pleasant lobe in section 36, Greenfield Township (O. G. S. 14587).

probably thins westward and wedges out near the main mass of the Hocking Valley tongue. It is not known to occur within the axial portion of the Hocking Valley tongue (fig. 4).

West of the Hocking Valley tongue, the Cuyahoga formation, undifferentiated, also appears to be transitional between the Black Hand and Raccoon members (fig. 4). Intertonguing with the Raccoon member to the west is shown by the sequence of alternating mudstone and sandstone north of Tarlton (O. G. S. 14546). The relationship between the Cuyahoga formation, undifferentiated, and the Black Hand is shown only in section 30, Madison Township (O. G. S. 14571), where the fine-grained sandstone underlies a thin, western prolongation of the Hocking Valley tongue.

The outcrop of the Cuyahoga formation, undifferentiated, which is located northwest of Lancaster (O. G. S. 14587), is unique because the unit overlies Black Hand sandstone (fig. 25). The Cuyahoga formation, undifferentiated, at this locality occurs in a portion of the stratigraphic interval occupied by the Black Hand three-quarters of a mile to the southeast at Mt. Pleasant. It is interpreted as representing a transition from the Black Hand sandstone of the Pleasant lobe to the finer beds of the Raccoon which are exposed approximately 2 miles to the west and southwest. The underlying Black Hand sandstone is interpreted as a westward prolongation, of unknown thickness and extent, of the Pleasant lobe.

Age

At present no more is known about the age of the Cuyahoga formation, undifferentiated, than the fact that it is early Mississippian and is equivalent to some part of the Kinderhook and Osage series of the upper Mississippi Valley.

OSAGE SERIES

LOGAN FORMATION

Definition

E. B. Andrews (1870, p. 62, 76, 79, 80, 87) used the name "Logan" for $133\frac{1}{2}$ feet of fine-grained, thin-bedded sandstone underlying either the Maxville limestone or the Coal Measures. The type area is at Logan, Hocking County.

In 1915 Hyde (p. 771-779) divided the Logan formation into three members, in ascending order, the Byer, Allensville, and Vinton. He noted that a fourth member, the Rushville, might be regarded as the youngest member of the Logan. Later, (1921, p. 152-154) he reclassified the Berne member, removing it from the Cuyahoga formation and assigning it to the base of the Logan formation, a classification followed by all subsequent workers.

In the same paper (1921, p. 151, 152), Hyde correlated the Berne member with the Buena Vista sandstone of western Scioto County, a classification which placed in the Logan formation the overlying Rarden, Vanceburg, Churn Creek, and Portsmouth members, which previously had been considered members of the Cuyahoga. Although Stockdale (1939, p. 131) regarded Hyde's (1921) correlation as erroneous, Holden (1942) persisted in equating the Berne and Buena Vista. Subsequently, Fagadau (1952, p. 12, 13) re-established Hyde's earlier (1915) classification.

Facies

Holden (1942, p. 53, 54) applied to the Logan formation a facies classification of the type which Hyde had proposed for the Cuyahoga. He moved the Scioto Valley shale facies and Vanceburg sandstone facies of Hyde from the Cuyahoga formation to the Logan formation and established in their places a single facies of the Cuyahoga, the Henley shale facies. He established a third facies of the Logan, the Pretty Run sandstone facies, which included the Logan formation in its occurrence from eastern Scioto County north to Wayne County. The Logan formation of Fairfield County is included in the Pretty Run sandstone facies. Holden's classification of the Logan formation is shown in table 3 and the areal distribution of his three facies is shown in figure 26.

Ten years later Fagadau re-established Hyde's original classification (1915) of the Cuyahoga formation (table 1) and modified Holden's facies classification of the Logan. He retained the Pretty Run sandstone facies and combined Holden's Scioto Valley shale facies and Vanceburg sandstone facies into a single unit, the New Boston siltstone facies, consisting, in ascending order, of the Diffon Hill and Vinton members (table 4).

The Berne, Byer, and Allensville members of the Logan grade into the siltstones and shales of the Diffon Hill member in southern Ohio. Fagadau (1952, p. 19) was able to trace a distinctive faunal zone, the Allorisma winchelli zone, which is present in the lower part of the Allensville in Fairfield County, into southern Ohio, where it occurs from 2 to 5 feet below the top of the Diffon Hill member. A higher faunal zone, the Dictyoclostus agmenis zone, occurs within the Vinton in both the Pretty Run sandstone facies and the New Boston siltstone facies. Fagadau (1952, p. 19) traced it into the Haldeman member of the Brodhead formation of Kentucky.

Table 3. - SUBDIVISION OF THE LOGAN FORMATION PROPOSED BY HOLDEN

Vanceburg siltstone facies	Scioto Valley shale facies	Pretty Run sandstone facies
		Rushville shale member
Vinton sandstone member	Vinton sandstone member	Vinton sandstone member
Churn Creek siltstone and shale member		Allensville conglomerate member
Vanceburg siltstone member	Portsmouth shale member	Byer sandstone member
Rarden shale member		
Buena Vista sandstone member	Buena Vista sandstone member	Berne conglomerate member

Table 4. - SUBDIVISION OF THE LOGAN FORMATION PROPOSED BY FAGADAU

New Boston siltstone facies	Pretty Run sandstone facies
	"Rushville member"
Vinton member	Vinton member
Diffon Hill member	Allensville member
	Byer member
	Berne member

Figure 26. - Facies of the Logan formation (after Holden, 1942, fig. 3).

Age

Fagadau (1952, p. 131-150) concluded that the Logan is equivalent to the Brodhead formation of Kentucky. He pointed out that the Brodhead contains at least two faunal zones, the lower zone strongly suggesting an Upper Burlington equivalence and the upper zone probably equivalent to the lower part of the Keokuk. The Logan, therefore, is equivalent to the Upper Burlington and lower Keokuk of the Mississippi Valley and is of medial Osage age.

Subdivisions

Berne Member

Definition

J. E. Hyde (1915, p. 674) used the name "Berne member" for a unit which consists largely of pebbles and rests on the surface of the Black Hand member of the Cuyahoga formation. In some localities shales and moderately coarse grained sandstones are found. According to Hyde, the thickness ranges from 1 to 20 feet. The member was named for exposures in Berne Township, Fairfield County.

Distribution

The Berne member is present throughout most of Berne Township, in southeastern Hocking Township, and in western Madison Township. Its outcrop pattern is approximately the same as that of the Cuyahoga-Logan contact, which is shown on the geologic map (pl. 1).

In eastern Berne Township the Berne member passes below drainage. No exposures are known in Richland or Rush Creek Townships. North of Berne Township the bedrock surface is largely obscured by glacial drift. The northernmost outcrops of the Berne occur in the southern tier of sections in Pleasant Township, at Mt. Pleasant in section 31 (O. G. S. 14567), and in section 33 where the Wheeling Road descends the west wall of the valley of Pleasant Run (O. G. S. 14570). In the western part of the county the strata of the Logan formation have been removed by erosion. The westernmost exposure of the Berne occurs on a high hill in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ of section 27, Madison Township (O. G. S. 14593).

It is not certainly known that the Berne member is present in the westernmost exposures of the Logan formation in Madison and Hocking Townships. In several localities the Logan has been mapped at the crests of isolated hills which stand a little higher than the surrounding hills. The recognition of the Logan on these hills is based on the occurrence of fine-grained, Byer-like sandstone which is represented by fragments in the thin soil above the massive ledges of the Black Hand. Ordinarily there is no evidence that the Berne is present. The member has a tendency, however, to be readily obscured by weathering, a fact which may account for its apparent absence in the westernmost occurrences of the Logan formation. It is also possible in a few instances that the fragments of sandstone identified as Byer are not in place but are glacial erratics.

More convincing evidence of the local absence of the Berne is found in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 12, Madison Township (O. G. S. 14558). Here massive conglomeratic sandstone identified as Black Hand appears to be immediately overlain by the very fine grained sandstone of the Byer member. The Black Hand and Byer are separated by a short horizontal interval, but no vertical interval; the absence of the Berne, while not conclusively demonstrated, is strongly suggested.

Lithologic Character

The lithologic character of the Berne member is extremely variable. In any one exposure it may range from clay or shale to conglomerate. The Berne is readily distinguished from the siltstone to fine-grained sandstone of the overlying Byer member because of the almost invariable occurrence of at least some pebbly sandstone or conglomerate.

In a general sense the lithologic character of the Berne is much like that of the underlying Black Hand. Separation of the Berne from the Black Hand is impeded by lack of diagnostic features which typify the Berne throughout the outcrop area. In some localities the base of the Berne is marked by an abrupt change in grain size, or decrease in sorting. Commonly pebbles are considerably more abundant than in the Black Hand. In other outcrops the presence of bedding has been used to distinguish the Berne from the massive sandstone of the Black Hand. Variable grain size, bedding, and local pebbly zones are known to occur within the Black Hand, so that these criteria for the recognition of the Berne may be used only where the stratigraphic position is clearly known. Another criterion for the recognition of the Berne member is its relative lack of resistance to weathering, a distinctive characteristic wherever the ledge-forming tendency of the Black Hand is developed. In naturally occurring exposures an abrupt change in slope occurs at the top of the Black Hand. The Black Hand forms bold ledges, but the overlying strata are usually largely covered and form gentle slopes. As a result the only excellent exposures of the Berne member occur on the faces of the few abandoned quarries from which the underlying Black Hand has been excavated.

Almost everywhere the Berne member includes beds of coarse-grained sandstone or conglomeratic sandstone consisting of rounded quartz pebbles in a matrix of poorly sorted ferruginous sand (fig. 27). The pebbles are usually smal-

Figure 27. - Friable conglomeratic sandstone of the Berne member in section 12, Madison Township (O. G. S. 14560). Pick rests on the top of the Black Hand sandstone.

ler than half an inch in diameter, but pebbles as large as an inch in diameter are not uncommon. The sand is largely subangular, but much of the angularity is due to abundant secondary crystallization of quartz. Siltstone, fine-grained sandstone, and medium-grained sandstone are common. In some instances coarse-grained or conglomeratic sandstone occurs as lenses or stringers in finer grained sandstone. The rapid variation in grain size is particularly well displayed in the quarries east of the Hocking River (O. G. S. 12110, 12454) and in a stratigraphic section (O. G. S. 7543) measured in section 11, Berne Township (T. 13 N.). In another stratigraphic section (O. G. S. 14570) measured in section 33, Pleasant Township, the strata thought to represent the Berne consist entirely of fine- to medium-grained sandstone. West of the Hocking Valley the sandstones of the Berne are usually coarse and conglomeratic, but fine-grained sandstone is not unknown. There is a general tendency for the finer grained strata to display thin or thin to medium bedding and for the coarser strata to be massive. Crossbedding occurs in a few outcrops.

The sandstones of the Berne are notably ferruginous. Hydrous iron oxide occurs interstitially, as coatings on individual sand grains, and as irregular bands and streaks visible on the face of the outcrop.

The most frequently noted colors for the sandstone are moderate yellowish brown (10 YR 5/4) and dark yellowish orange (10 YR 6/6). In several localities the color light brown (5 YR 5/6) has also been noted. In any one outcrop the color may vary to extremes which include very light gray (N8), dark reddish brown (10 R 3/4), dusky brown (5 YR 2/2), and yellowish gray (5 Y 7/2). A unique, thin, sandy mudstone colored very dark red (5 R 2/6) lies at the base of the Berne member in a stratigraphic section (O. G. S. 14559) measured in the NE$\frac{1}{4}$ of section 9, Berne Township (T. 13 N.).

Layers and lenses of clay, shale, or mudstone ranging in thickness from an inch to more than a foot occur locally in the Berne member. They are generally rather light in color; colors noted in measured stratigraphic sections include light gray (N7), light olive gray (5 Y 5/2), pale olive (10 Y 6/2), greenish gray (5 GY 6/1), dusky yellow (5 Y 6/4), and moderate yellowish brown (10 YR 5/4). In several instances a thin argillaceous layer separates the lowest sandstone of the Berne from the underlying Black Hand sandstone.

Thickness

The thickness of the Berne member, where it is recognized in Fairfield County, ranges from approximately 1 foot to slightly more than 30 feet. South of Brushy Fork (O. G. S. 14595) both the upper and lower contacts are exposed, and a thickness of 1.1 feet was determined. The fact that it may be thinner elsewhere is suggested by an outcrop (O. G. S. 14558) located 3 miles to the west in the NW$\frac{1}{4}$ of section 12, Madison Township, where the Berne member appears to be absent. Here a short horizontal interval, but no vertical interval, separates the Byer member from beds which are recognized as Black Hand.

The greatest known thickness of the Berne member occurs along the road in the NE$\frac{1}{4}$ of section 36, Hocking Township (O. G. S. 14562). A total thickness of 30.6 feet was measured. A covered interval of 2.1 feet obscures the Berne-Byer contact. The maximum thickness of the Berne, therefore, may be as great as 32.7 feet.

Swick (1956, p. 89) noted a thickness of less than 2 feet for the Berne in approximately the same locality. According to his description the Black Hand is overlain by a 1-inch layer of white, plastic clay which is in turn overlain by 1 foot, 7$\frac{1}{2}$ inches of friable conglomeratic sandstone. He recognized the clay and sandstone as Berne and noted that it was overlain by siltstone which he referred to the Byer member. The thickness of the Byer was not measured.

The present writer found the Black Hand to be overlain by 1.8 feet of exceedingly friable, coarse-grained sandstone. The sandstone is overlain by a foot of light gray, plastic clay. The absence of the lower 1-inch clay bed which was noted by Swick is not disturbing. It may have been concealed by slumping of the overlying sandstone or by talus from the overlying sandstone. The exact position of Swick's section is unknown, and the clay may have been a lens which wedged out in a short distance. The writer believes that the friable sandstone is the same bed described by Swick.

A covered interval 22.5 feet thick and containing fragments of conglomerate separates the 1-foot clay layer from the upper part of the member which consists, in ascending order, of 2.5 feet of fine-grained sandstone, 1 foot of conglomerate, a covered interval 0.6 foot thick, and 1.2 feet of poorly sorted, fine- to coarse-grained sandstone. Separated from the uppermost sandstone by a covered interval 2.1 feet thick is 20 feet of very fine grained, thin-bedded sandstone typical of the Byer member. Float of coarse-grained sandstone recognized as Allensville occurs on the hillside immediately above the outcrop of the Byer member.

The cause of the great discrepancy in thickness at this locality is unknown. If Swick's identification of the Byer member is accurate, the presence of a marked disconformity of at least local extent between the Berne and Byer is implied. No such occurrence, however, has been reported anywhere else by previous students of the Logan formation, and it seems more plausible to assume that the large covered interval measured by the writer contains some fine-grained strata which were observed by Swick and mistakenly identified as Byer.

The great variability of the thickness of the Berne member is demonstrated in a number of outcrops lying within 4 miles to the southwest and southeast of the section described above. A mile to the southwest, at the head of the ravine which lies just west of Ridge Road at the Boys' Industrial School, the Black Hand is overlain by a bed of conglomerate which is a foot or slightly more in thickness. Above the conglomerate, which constitutes the Berne member, fragments of siltstone or fine-grained sandstone thought to belong to the Byer may be dug out of the hillside. A short distance to the south, along Ridge Road, at the foot of the hill immediately south of the 1170-foot crossroads in the NE$\frac{1}{4}$ of section 1, Madison Township (O. G. S. 14566), a thickness of 2.2 feet was determined in an outcrop in which both the upper and lower contacts are well exposed. Within a quarter of a mile to the south a thickness of 17 feet was determined in the winding farm lane and on Ridge Road immediately north of the farm lane entrance (O. G. S. 14565). Most of the member is covered here, and it would be difficult to prove conclusively that the lower portion, recognized as Berne, is not actually Black Hand. Its lithologic character, however, is more similar to the lithologic character of the conglomeratic portions of the Berne than it is to the conglomeratic portions of the Black Hand.

A little more than a mile to the southwest of the intersection of Ridge Road and the farm lane, the Berne seems to be absent in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 12, Madison Township (O. G. S. 14558). Three-quarters of a mile east of the last exposure the member is 12.1 feet thick in the NE$\frac{1}{4}$ of section 12, Madison Township (O. G. S. 14560).

Approximately 3 miles to the east of the last-mentioned outcrop, in the SW$\frac{1}{4}$ of section 9, Berne Township (T. 13 N.) (O. G. S. 14595), the Berne member, as previously noted, is 1.1 feet thick. In a quarry in the NE$\frac{1}{4}$ of the same section (O. G. S. 14599), the thickness of the Berne has increased to 4 feet.

Similar variation in thickness is displayed east of the Hocking Valley. Three stratigraphic sections were measured along an east-west line 2 miles in length in the northern parts of sections 26, 27, and 28, Berne Township. In the westernmost one

(O. G. S. 12454), located in an abandoned quarry in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 28, the Berne member is 11. 2 feet thick. Approximately three-quarters of a mile to the east, in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ of section 27 (O. G. S. 14564), the thickness of the Berne is at least 1. 4 feet and no more than 3. 4 feet. Slightly more than a mile farther east, in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 26 (O. G. S. 14609) the thickness of the Berne, measured in a pipeline trench which has since been filled in, is 10 feet.

The greatest thickness east of the Hocking Valley was observed in the SE$\frac{1}{4}$ of section 11, Berne Township (T. 13 N.) (O. G. S. 7543), where a thickness of 25. 3 feet was determined.

Stratigraphic Relations

Where it is exposed in Fairfield County the Berne member overlies the Black Hand member of the Cuyahoga formation and underlies the Byer member of the Logan formation. In defining the Berne member in 1915, Hyde considered it to be the uppermost member of the Cuyahoga formation because of its lithologic similarity to the Black Hand. However, he suggested (1915, p. 677) that from the point of view of historical succession the Berne might be more closely allied to the Logan formation. This conclusion was based on the following considerations (1915, p. 677, 678): (1) The basal contact is sharp, and in some localities it is obviously disconformable. (2) In some areas the upper contact is transitional. (3) Beds similar to those of the Byer member occur within the Berne east of the "Hocking Valley province". (4) The fauna of the Berne member suggests the existence of environmental conditions more similar to the conditions of Logan deposition than to the conditions of Black Hand deposition.

Later, Hyde (1921, p. 152-154) classified the Berne as the basal member of the Logan formation. This classification has been followed in all subsequent investigations of the Ohio Waverly.

The basal contact of the Berne member in Fairfield County is sharp in all exposures (fig. 28). In a few outcrops it appears to be slightly undulatory, but nowhere is it obviously disconformable. However, disconformities have been noted locally in Hocking County (Hyde, 1915, p. 677; Hall, 1951, p. 43) and in Licking County (Swick, 1956, p. 32). The Berne-Byer contact is sharp in Fairfield County, but there is no evidence of disconformity.

The surface of the Cuyahoga formation (fig. 31) is not a uniformly dipping plane, but rather it is an irregular surface. The Black Hand sandstone in Hocking, Madison, and western Berne Townships, where it is present at maximum thickness, forms a prominent structural and topographic high. A second structural high, though of smaller magnitude, has been noted east and south of Berne Township in Marion and Falls Townships, Hocking County, where a small lobe of Black Hand sandstone rises above drainage (Merrill, 1950, p. 77, 78; Hyde, 1953, p. 95-98). Merrill (1950, p. 77) noted the presence of fine-grained, fossiliferous sandstone in the intervening trough. The structure of the Cuyahoga surface, with a syncline-like trough flanked by anticline-like highs is thought to be depositional rather than tectonic in origin (p. 91-92).

Hyde (1953, p. 98) noted that the Berne member is thinnest where it overlies the axial portion of the Hocking Valley tongue of the Black Hand. He stated that here it is usually 1 to 3 feet thick and consists of massive, coarse-grained sandstone in which the occurrence of abundant pebbles is common. He noted further that ". . . in the low sag between the crests of the Black Hand member, the bed is thicker, commonly from 8 to 15 or even 20 feet. Beds of moderately fine grained sandstone and sandy shale are present, and the pebbles while very abundant in some layers, are apt to be smaller" (Hyde, 1953, p. 99).

Figure 28. - Bedded sandstone of the Berne member resting with sharp contact on the Black Hand sandstone in section 10, Berne Township (O. G. S. 12110). Pick rests on top of the Black Hand sandstone.

To some extent the writer's observations in Fairfield County agree with those of Hyde. East of the Hocking River in Berne Township the Berne member is usually 10 feet or more in thickness, and includes fine-grained sandstones and thin shales. The only known exception occurs in section 27, Berne Township (O. G. S. 14564), where the thickness of the Berne lies somewhere between 1. 4 and 3. 4 feet. The exposed portion of the Berne in this outcrop consists of medium- to coarse-grained conglomeratic sandstone.

The greatest thickness noted for the Berne in eastern Berne Township is a thickness of slightly more than 25 feet in the SE$\frac{1}{4}$ of section 11 (T. 13 N.) (O. G. S. 7543). Merrill (1950, p. 86) noted a thickness of nearly 30 feet in northwestern Marion Township, Hocking County. According to Merrill (1950, pl. VIII), the axis of the trough which occurs in the surface of the Cuyahoga formation lies a short distance east of the eastern border of Berne Township. The Berne member, therefore, seems to be unusually thick where it overlies the sag in the Cuyahoga surface.

The minimum thicknesses noted for the Berne member occur west of the Hocking River where the Berne member overlies the axial portion of the Hocking Valley tongue of the Black Hand member. In many localities the Berne is no thicker than 2 or 3 feet. In an exposure northeast of Revenge in Madison Township (O. G. S. 14558) it is probably absent. There are several localities west of the Hocking River, however, where the thickness of the Berne exceeds 10 feet. These include the exposure in southeastern Hocking Township (O. G. S. 14562), where the Berne is more than 30 feet thick.

The surface of the Black Hand sandstone west of the Hocking River is undulatory. The Berne appears to be relatively thin over the high portions of this surface and relatively thick where it overlies depressions in the surface of the Black Hand. This relationship is particularly well shown in southeastern Hocking Township and along the ridge north of Blue Valley in Berne Township. At the Boys' Industrial School in southeastern Hocking Township the Berne member is thin, and the surface of the Black Hand is relatively high. Within a mile to the northeast the surface of the Black Hand descends approximately 100 feet and the Berne member thickens to more than 30 feet. The difference in elevation due to the regional dip alone should be less than 25 feet. Nearly 2 miles to the east of the last exposure the surface of the Black Hand lies at approximately the same elevation on the crest of the ridge north of Blue Valley School. Fragments of fine-grained Logan-like sandstone occur on the ridgetop, but there is no evidence of the Berne member. Prior to the imposition of the regional dip, the unusually thick deposit of the Berne member occupied a depression in which the elevation of the Black Hand surface was at least 75 feet lower than it was at the Boys' Industrial School and probably 50 to 60 feet lower than it was 2 miles to the east where it is exposed on the ridge north of Blue Valley School.

A similar relationship is shown in section 12, Madison Township. Near the western border of the section (O. G. S. 14558) the Berne member appears to be absent. Nearly three-quarters of a mile to the east (O. G. S. 14560) the Berne is slightly more than 12 feet thick, and the top of the Black Hand has descended 38 feet. Here the Berne consists almost entirely of conglomeratic sandstone. The difference in elevation is probably too great to be accounted for by the regional dip alone. Furthermore, the rate of eastward descent at the top of the Black Hand decreases markedly. Half a mile to the north-northeast of stratigraphic section O. G. S. 14560 the elevation of the top of the Black Hand has increased by about 20 feet.

The gross relief of the Cuyahoga surface, which is expressed by the two crests of Black Hand sandstone and the intervening trough, is considered to be depositional in origin. There is no evidence of a disconformity between the Cuyahoga and Logan formations in the vicinity of the trough. Merrill (1950, p. 87) found that the Black Hand-Berne contact in the trough in Marion and Falls Township, Hocking County, is gradational.

West of the Hocking River it is apparent that the surface of the Black Hand is irregular and that the Berne is thickest where the surface is low and is relatively thin or absent where the surface of the Black Hand is high. Although an unmistakably disconformable Black Hand-Berne contact has not been observed in Fairfield County, there are several indications that the irregularity of the Black Hand surface in the axial portion of the Hocking Valley tongue may be due, at least in part, to erosion of pre-Logan age. The irregularity itself, of course, suggests disconformity, and the Black Hand-Berne contact is invariably sharp. The lithologic similarity of the Berne to the Black Hand and the marked decrease in fine-grained detritus in the Berne as the crest of the Hocking Valley tongue is approached suggest that the Hocking Valley tongue is the source for most of the sediments of the Berne in Fairfield County. If this interpretation is correct, the thicker portions of the Berne may represent the filling of channels cut into the Black Hand surface. Unfortunately, the data presently available are insufficient for confirmation of this hypothesis.

Age

Scattered fossils occur in the Berne member in Fairfield County. The writer found a single poorly preserved brachiopod in southeastern Berne Township (O. G. S. 7543), but Hyde (1953, p. 112, 113, 115) has noted the occurrence of brachiopods in a few other localities. Merrill (1950, p. 85, 86) and Hyde (1953, p. 100) reported fossils in the Berne member in northeastern Hocking County. Fagadau (1952, p. 29) reported a total of three brachiopod species and one gastropod species from the Berne of central and southern Ohio.

Weller and others (1948) indicated that the Logan formation is of medial Osage age and is equivalent to the upper part of the Burlington limestone and the lower part of the Keokuk limestone of the upper Mississippi Valley. Fagadau (1952, p. 132) concluded that the Logan formation represents the upper part of the Burlington and some part of the Keokuk. The Berne is presumably of late Burlington age.

Byer Member

Definition

Hyde, (1912, p. 211) gave the name "Byer" to the fine-grained sandstone underlain by the Berne member and overlain by the Allensville member of the Logan formation. The member was named for exposures in the railroad cuts east of the town of Byer, Jackson County (Hyde, 1915, p. 772-775).

Fagadau (1952, p. 30) concluded that the strata exposed in the type area are siltstones belonging to the Cuyahoga formation. He proposed that the name "Byer" be retained, but that strata exposed in a road cut on U. S. Route 33, three-quarters of a mile northwest of Logan, Hocking County, be considered as the type section.

Distribution

The Byer member is exposed throughout much of southeastern Fairfield County. Because the Berne member is relatively thin, the distribution of the basal portion of the Byer is approximated by the Cuyahoga-Logan contact which is shown on the geologic map (pl. 1).

The Byer is well exposed in much of Berne Township and in western Rush Creek Township. Its westernmost exposures are found at the crests of some of the higher hills in south-central Madison and central and southeastern Hocking Townships. Its northernmost exposures occur in central Pleasant Township and in the gorge of Rush Creek in Richland Township. Siltstone and shale which may belong to the Byer are found as far north as section 8, Richland Township, where they crop out along Indian Creek. To the east the Byer member passes below drainage in western Rush Creek Township. The easternmost good exposure occurs about a mile and a half south of Bremen in section 28, Rush Creek Township. Beds tentatively identified as Byer, however, are exposed just south of Turkey Run in the central part of section 36, Rush Creek Township.

Lithologic Character

The colors of the Byer member include several shades of olive, yellow, brown, and orange. The most frequently noted colors are dark yellowish orange (10 YR 6/6) and grayish orange (10 YR 7/4), but dusky yellow (5 Y 6/4), moderate yellowish brown (10 YR 5/4), and light olive brown (5 Y 5/6) are also common.

The grain size of the Byer ranges from silt and clay to fine-grained sand. Although the member consists of fine-grained sandstone in some localities, siltstone or very fine grained sandstone may be considered typical. Commonly scattered single grains or occasional layers one grain thick of medium-grained sand to granules occur in the upper part of the member. Typically the Byer is rather soft, probably because of a high argillaceous content.

Commonly the Byer is slightly micaceous. In some localities tiny crystal faces resulting from secondary crystallization of quartz may be seen. Hydrous iron oxide is abundant. It is present most commonly as stains on bedding surfaces and on the weathered faces of outcrops. In eastern Madison Township the basal few inches of the member are so heavily impregnated with hydrous iron oxide as to form a very heavy, hard, dark rock, boulders of which litter some of the hilltops where the superjacent strata have been removed by erosion.

Figure 29. - Berne and Byer members in section 28, Berne Township (O. G. S. 12454). Top of 5-foot pole is at base of Byer.

The Byer member is usually thin to medium bedded (fig. 29). In an abandoned quarry in section 28, Berne Township (O. G. S. 12454), where the exposure is relatively fresh, thick-bedded, very fine grained sandstones alternate with very thin bedded, silty mudstones.

Marine fossils, including, in order of decreasing abundance, crinoid columnals, brachiopods, and fenestellid bryozoans, are common in the Byer. The fossils tend to be concentrated in restricted beds which seem to differ from the rest of the member only in their fossil content.

Thickness

The thickness of the Byer member, where it is exposed in Fairfield County, ranges from 20 feet, or slightly more, to 60 feet. The member is thinnest where it overlies the axial portion of the Hocking Valley tongue of the Black Hand member in eastern Madison and southeastern Hocking Townships, and it thickens toward the east.

In section 12, Madison Township (O. G. S. 14558) the Byer member is 23 feet thick. A mile northeast of the Boys' Industrial School in southeastern Hocking Township (O. G. S. 14562) the Byer is at least 20 feet thick, but it is probably not much thicker than 22 feet. The greatest thickness determined for the member, 60 feet, occurs east of the Hocking River in section 27, Berne Township (O. G. S. 14564). The average thickness for the member in eastern Berne Township, however, is probably about 40 feet.

East of Berne Township the base of the member lies below drainage so that its thickness is unknown. It is not known whether the Byer continues to thicken to the east. Hyde (1953, p. 122) noted a thickness of 80 feet in northern Marion Township, Hocking County. Merrill (1950, p. 93), however, reported a maximum thickness of only 50 feet in northern Hocking County. Cuttings from an oil well (O. G. S. sample No. 676) located just east of the Fairfield County line in section 6, Jackson Township, Perry County, indicate a thickness of about 60 feet for the Byer member.

The variation in the thickness of the Byer member seems to reflect the gross configuration of the surface of the Cuyahoga formation. East of the Hocking River the thickness ranges from nearly twice to nearly three times the thickness present on the crest of the Hocking Valley tongue. Although somewhat subdued, the major irregularities of the Cuyahoga surface seem to be expressed in the upper surface of the Byer member (fig. 32).

Stratigraphic Relations

In Fairfield County the Berne-Byer contact is sharp. Except for the fact that it is sharp, there is no evidence of disconformity. Merrill (1950, p. 93, 94) found that the contact in northeastern Hocking County is gradational. Local disconformity at the base of the Byer is indicated in eastern Madison Township (O. G. S. 14558), where the Byer appears to rest directly on the Black Hand. Hohler (unpublished data, Ohio Division of Geological Survey files) noted the local absence of the Berne in some outcrops in Perry Township, Hocking County.

The upper contact of the Byer is commonly gradational. The gradation is expressed by the occurrence of scattered grains and occasional layers one grain thick of medium-grained sand to granules in the upper part of the Byer. The base of the Allensville, which overlies the Byer, has been arbitrarily placed at the base of the lowest bed in which medium- to coarse-grained sand predominates. In a few localities the transition beds are not present, and the Byer-Allensville contact is abrupt. Exposures in which the contact is well exposed are few, and the writer prefers to make no generalizations regarding the distribution of the transition zone.

Age

The Byer member contains marine fossils which include crinoid columnals, brachiopods, and fenestellid bryozoans. Weller and others (1948) considered the Logan formation to be of medial Osage age. Fagadau (1952, p. 132), in a detailed study of the Logan fauna in southern and central Ohio, reached a similar conclusion, and the writer has no new data that modify Fagadau's correlation.

Allensville Member

Definition

Hyde defined the Allensville as 0 to 39 feet of sandstone whose "chief characteristic is the occurrence of very coarse, excellently assorted, and usually well-rounded quartz grains" (Hyde, 1915, p. 775). Some finer grained detritus occurs in the Allensville in Fairfield County. The Allensville member overlies the Byer member and is overlain by the Vinton member of the Logan formation. The name is derived from exposures near the village of Allensville in western Vinton County. The name was first used by Hyde (1912, p. 211) without formal definition.

Distribution

Outcrops of the Allensville member are found only in the southeastern portion of the county. The most numerous exposures occur in Berne Township and in the western parts of Richland and Rush Creek Townships. The member is almost entirely below drainage in eastern Richland and Rush Creek Townships, but it is known in a single outcrop in southeastern Rush Creek Township. Here it was recognized in a roadside ditch south of Turkey Run in the central part of section 36. The northernmost exposures are located in Richland and Pleasant Townships along an east-west line which passes just north of Rushville. Farther north the bedrock surface is almost entirely covered by glacial drift. The westernmost outcrops occur on some of the hilltops in southeastern Hocking Township and eastern Madison Township.

Lithologic Character

The Allensville member is distinctive because of the occurrence of coarse-grained, ferruginous sandstone. Fine-grained sandstone, siltstone, and mudstone are important in some localities.

The color of the Allensville member does not differ appreciably from the color of the other siltstones and sandstones of the Cuyahoga and Logan formations. Grayish orange (10 YR 7/4) is common, but most abundantly noted by far are dark yellowish orange (10 YR 6/6) and moderate yellowish brown (10 YR 5/4). Considerable local variation occurs. In any one outcrop various shades of gray, olive, yellow, orange, brown, or red may occur. Accumulation of hydrous iron oxide on weathered surfaces results in very dark colors which approach black.

The typical coarse sandstones of the Allensville consist of medium to very coarse quartz sand in a matrix of hydrous iron oxide and detrital material no coarser than fine-grained sand. The beds are commonly massive, but the presence of bedding is not uncommon.

The relative abundance of coarse detritus varies greatly. In many outcrops the sandstone ranges from fine-grained sandstone with a few scattered coarse grains to coarse-grained sandstone with fines occurring interstitially. Sometimes the change is extremely rapid and results in the development of discrete layers or lenses of alternating coarse- and fine-grained sandstone which range in thickness from a fraction of an inch to several inches. In some outcrops the boundaries between the predominantly fine-grained and predominantly coarse-grained portions are indistinct.

The coarse-grained fraction of the Allensville almost always consists of medium-grained to very coarse grained sand, but granules occur in some outcrops. Pebbles are rare, but in a stratigraphic section measured in southern Pleasant

Township (O. G. S. 14570) Allensville float blocks contain scattered pebbles as large as an eighth of an inch in diameter. In contrast to this the Allensville in a stratigraphic section (O. G. S. 14569) measured approximately 2 miles to the east consists entirely of fine- to medium-grained sandstone.

The sand grains of the Allensville consist almost entirely of quartz which is subangular to subrounded. Much of the angularity is due to the secondary crystallization of quartz. In a few localities abundant weathered feldspar is present. The member is commonly slightly micaceous.

Hydrous iron oxide is notably concentrated in the coarser portions of the member. It occurs as coatings on individual grains, as an interstitial filling, and occasionally as heavy sinuous bands.

The sandstone is generally rather friable, but locally a weak ledge-forming tendency is displayed. Where bands of hydrous iron oxide occur, the sandstone may be quite hard. Commonly the float of the Allensville consists almost entirely of blocks containing hydrous iron oxide bands. These are left behind after the weathering and disintegration of the more friable portions.

In several outcrops there are one or more units consisting exclusively of siltstone, or very fine grained sandstone. These strata commonly range from 1 to 3 feet in thickness, and usually they are relatively soft, somewhat micaceous, and display thin or medium bedding.

The greatest exposure of fine-grained clastic rocks occurs in the gorge of Rush Creek near Rushville in Richland Township. The entire thickness of the Allensville is exposed in a stratigraphic section (O. G. S. 14607) measured in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 33 on the east bank of Rush Creek. Very fine grained sandstone identified as Byer lies at stream level and is overlain by 0. 6 foot of medium- to coarse-grained sandstone which forms the base of the Allensville member. The basal sandstone grades upward into 6. 3 feet of gray siltstone which is rather soft, displays poorly developed thin bedding, and contains scattered pelecypods with closed valves. Hyde (1915, p. 777) noted that these pelecypods characterize the *Allorisma winchelli* horizon, and that they are almost always found in life position. The siltstone in turn grades upward into 9. 6 feet of mottled gray, very fine grained sandstone, which is massive, very hard, and unusual because of its tendency to spall on the nearly vertical, stream-cut cliff. Above the very fine grained sandstone is slightly more than 10 feet of typical Allensville consisting largely of medium- to coarse-grained sandstone. However, about 3 feet below the top of the member is another unit of very fine grained sandstone more than 2 feet thick.

The Allensville beds lack persistence. Less than a quarter of a mile to the north, on the north side of the new highway bridge in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ of section 28 (O. G. S. 14608), the Allensville sequence is similar but by no means identical with the sequence described above. Slightly over half a mile to the south (O. G. S. 12118) the interval of the fine-grained beds is occupied by coarse-grained sandstone. When the section was visited by the writer, the interval of the fine-grained beds was covered, but Hyde (1953, p. 131) noted that the Allensville at this locality consists of more than 20 feet of very coarse grained sandstone.

Thickness

Outcrops in which both the upper and lower contacts of the Allensville are exposed are rare. A precise statement of the thickness, therefore, is not possible. In general the thickness ranges from a minimum which may be as great as 10 feet, but no more than 15 feet, to a maximum of more than 20 feet. The greatest known thickness occurs in the gorge of Rush Creek in section 33, Richland Township (O. G. S. 14607), where the member is 26. 6 feet thick. Here there are an unusually large number of fine-grained beds.

Stratigraphic Relations

The Allensville member lies with probable conformity above the Byer member and below the Vinton member. The Byer-Allensville contact is commonly gradational, the gradation expressed by the occurrence of scattered grains of medium- to coarse-grained sand in the upper part of the Byer. The base of the Allensville has been arbitrarily considered to lie at the base of the lowest bed in which medium- to coarse-grained sand predominates. This contact is usually sharp.

In a few exposures there is no evidence of gradation. The very fine grained clastic rocks of the Byer are immediately overlain by coarse-grained Allensville. Locally, as at Rushville (Hyde, 1915, p. 777), the contact may be disconformable.

The Allensville-Vinton contact is seldom exposed. In its few exposures it is sharp, but there is no evidence of disconformity.

Age

Marine fossils, including brachiopods, pelecypods, and crinoid columnals, are present in the Allensville member in Fairfield County. Fagadau, in a study of the Logan fauna (1952, p. 132), confirmed the earlier correlation of Weller and others (1948), in which the Logan was considered equivalent to the upper part of the Burlington limestone and the lower part of the Keokuk limestone of medial Osage age. The Allensville lies somewhere within the upper Burlington-lower Keokuk interval.

Vinton Member

Definition

Hyde (1912, p. 212) used the term "Vinton member" for the fine-grained sandstones and shales overlying the Allensville member in Fairfield County. In 1915 (p. 778, 779) he formally defined it as the uppermost member of the Logan formation and noted that the name was taken from exposures in Vinton County. It is possible that a fifth member of the Logan formation, the Rushville member, overlies the Vinton in Perry County, but it is absent in Fairfield County.

Distribution

The Vinton member is exposed in Berne Township east of the Hocking River and throughout much of Rush Creek and Richland Townships. A few scattered exposures are known in the southeastern part of Pleasant Township. In the northeastern part of the county the bedrock surface is covered almost entirely by drift, through which a few bedrock highs protrude. The Vinton is exposed on two such highs in eastern Walnut Township. The more southerly is located in section 24, in a ravine half a mile south of New Salem. The northernmost exposure is located just south of the 1113-foot crossroads about 2 miles north of New Salem.

Lithologic Character

The Vinton member consists of mudstone, siltstone, and very fine grained to fine-grained sandstone. It is readily distinguished from the underlying Allensville because of the total absence of grains coarser than fine-grained sand. It is extremely difficult, however, to distinguish the Vinton from the Byer member. Recognition of the Vinton is certain only where the stratigraphic position of the rocks in question is known.

The color of the Vinton member is much like the color of the other members of the Logan formation, but olive and yellow hues predominate rather than the orange and brown hues which are so common in the underlying rocks. In fresh exposures the color ranges from a medium shade of gray to medium bluish gray (5 B 5/1) and light bluish gray (5 B 6/1). Usually the member is weathered, and the most frequently occurring colors are light olive gray (5 Y 5/2), moderate olive brown (5 Y 4/4), and yellowish gray (5 Y 7/2). The extremes in color include moderate brown (5 YR 4/4) and dark yellowish orange (10 YR 6/6). Many shades between these colors and gray are found. Locally, especially near the top of the member, a reddish tint is common. Iron staining on weathered surfaces produces a very dark mottled effect.

Fagadau (1952, p. 43) found that the Vinton member in central Ohio is divisible into three units: a basal shaly siltstone and silty shale unit; a middle unit consisting of fine-grained fossiliferous sandstone; and an upper siltstone and shale unit.

The threefold division is apparent in some of the better exposed sections. Ordinarily, however, the member is not particularly well exposed, and little more is apparent than the fact that siltstone is the dominant lithologic type.

The best exposures of the Vinton member are located in the gorge of Rush Creek in Richland Township. Three stratigraphic sections in which the Vinton is well displayed were measured in the gorge. The northernmost (O. G. S. 14608) is located on the east bank of Rush Creek just north of the new highway bridge in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ of section 28. The upper part of the section was described from road cuts just east of the new bridge. A second stratigraphic section (O. G. S. 14607) is also located on the east bank less than 0. 2 mile south of the bridge in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 33. The southernmost section (O. G. S. 12118) is located on the west bank about three-quarters of a mile south of the new bridge. The three divisions of the member are more apparent in the gorge than they are anywhere else, an occurrence which may be explained probably by the fact that the member is not so well exposed elsewhere. These sections may be regarded as typical. Certainly the member is not greatly different elsewhere in the county.

The lower unit in the Rush Creek gorge is approximately 30 feet thick and consists predominantly of siltstone, but some mudstone and a few thin beds of fine-grained sandstone may be present. In a few exposures to the west in Berne Township, as much as 8 feet of soft mudstone, which grades upward into siltstone, forms the base of the Vinton member. The siltstone is thin bedded, micaceous, and displays a very fine lamination, which is brought out by differential accumulation of hydrous iron oxide. A few thin layers of clay ironstone concretions occur in the lower unit in the gorge. Fossils are rare, but a few brachiopods were found south of Bremen in Rush Creek Township (O. G. S. 14581).

Resting on the lower unit with sharp contact is approximately 11 feet of hard thin-bedded to massive siltstone to very fine grained sandstone. The most distinctive feature of this unit, the middle unit of the Vinton member, is the abundance of its fossils, which include brachiopods, crinoid columnals, and a few pectinid pelecypods. The brachiopods are particularly abundant, and on many the spine bases are excellently preserved.

The upper unit consists of alternating mudstone, siltstone, and very fine grained to fine-grained sandstone. The best known exposure occurs in the southernmost of the three sections in the Rush Creek gorge (O. G. S. 12118), where it is nearly 100 feet thick. The sandstones form the thickest portions of the sequence, reaching thicknesses as great as 20 feet. Except for the mudstones, which are blocky and soft, thin bedding is dominant. Some of the sandstones, however, are massive. The sandstones in many places are very finely laminated, and in a few instances fine cross-lamination occurs. The lamination is visible only because of the differential concentration of hydrous iron oxide. Fossils, including brachiopods, bryozoans, and crinoid columnals, occur sparingly in the siltstones and sandstones of the upper unit. The fossils tend to occur within relatively thin restricted layers, and the intervening beds are commonly practically barren.

In a few localities in Berne and Rush Creek Townships the contact between the Vinton member and the sandstone of the overlying Pottsville group is exposed (O. G. S. 14555, 14556, 14583). The uppermost part of the Vinton gives the impression of having been altered, in one instance to a depth of about 15 feet. The beds lose their characteristic olive, yellow, and brown colors and appear to be bleached. Hydrous iron oxide is largely absent, or it occurs only as small scattered specks or very thin concentric bands. It may, however, be heavily concentrated in fractures such as joint planes. The uppermost 2 to 3 feet may consist of light-colored, plastic, slightly silty clay. The writer has included the clay in the Vinton because in section 25, Rush Creek Township (O. G. S. 14583), it grades downward into typical Vinton siltstone and is overlain with sharp contact by typical Pottsville sandstone.

Thickness

Precise determination of the thickness of the Vinton is rendered impossible by the disconformable nature of its upper contact and also by the very limited extent of the overlying strata. The minimum thickness for the member was determined in sections 13 and 14, Berne Township (O. G. S. 14555) where the Vinton is approximately 115 feet thick. About half a mile to the south, at Pleasant Hill, a thickness of about 130 to 140 feet is indicated. In southeastern Berne Township the member is 130 to 140 feet thick.

Eastward, in Rush Creek Township and as far north as Rushville in Richland Township, the thickness is about 160 to 180 feet. Just east of the Fairfield-Perry County line, in the NW$\frac{1}{4}$ of section 6, Jackson Township, Perry County, a thickness of approximately 215 feet is indicated in oil well cuttings (O. G. S. sample No. 676).

Stratigraphic Relations

The Vinton overlies the Allensville member throughout the area of its occurrence in Fairfield County. The contact is invariably sharp and is marked by an abrupt change from the coarse-grained sandstone of the Allensville to the basal siltstone or mudstone of the Vinton (fig. 30). The relationship between the two members, however, appears to be one of conformity.

The Vinton member is usually overlain by the Pottsville group of the Pennsylvanian system. In some areas it may be overlain by the Maxville limestone. Flint (1951, p. 15-18) in Perry County and Merrill (1950, p. 112-114) in northern Hocking County summarized the evidence for a disconformity at the base of the Maxville. Undoubtedly the Maxville, if it is present in Fairfield County, lies disconformably on the Vinton.

The disconformable relationship of the Vinton-Pottsville boundary is not apparent in any single outcrop. However, the presence of a disconformity may be inferred from the variability of the thickness of the Vinton. Consideration of the thickness of the Vinton suggests that the relief of the contact may be nearly 100 feet. Some of the variation in the thickness of the Vinton may be due to the accumulation of a greater thickness in the eastern part of the county. Little evidence exists in Fairfield County which either confirms or invalidates this hypothesis.

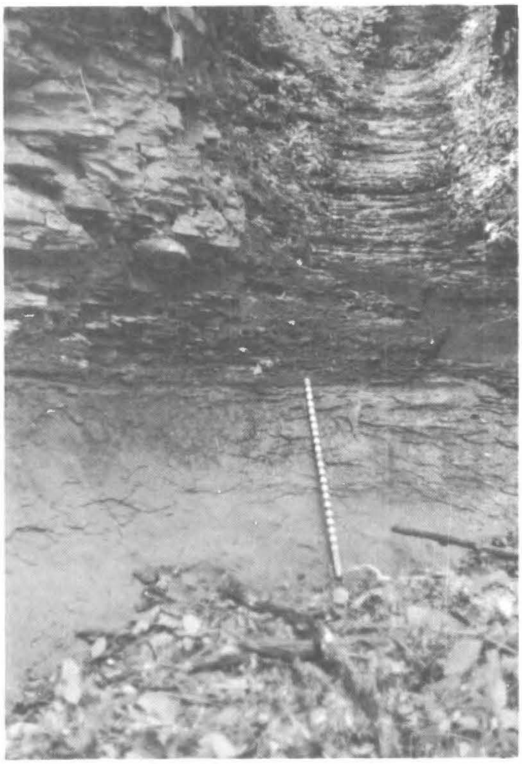


Figure 30. - Allensville-Vinton contact in section 33, Richland Township (O. G. S. 12118). Top of 5-foot pole is at base of Vinton member.

Age

Marine fossils, including brachiopods, pectinid pelecypods, bryozoans, and crinoid columnals, are abundant in the Vinton member. The fossiliferous beds of the middle unit constitute the Dictyoclostus agmenis zone (Productus arcuatus zone of earlier writers), which Fagadau (1952, p. 19) was able to trace southward into the Haldeman member of the Brodhead formation of Kentucky. Weller and others (1948) and Fagadau (1952, p. 132) consider the Logan to be equivalent to the upper part of the Burlington and some part of the Keokuk of the Mississippi Valley. The Vinton member, therefore, is of medial Osage age.

"Rushville" Member

Andrews (1879, p. 137) introduced the name "Rushville group" to denote about 50 feet of fossiliferous clay shale and a thin limestone lying between the Vinton member and the Maxville limestone in Perry County. The unit presumably was named after the village of Rushville in Richland Township, Fairfield County.

The status of the "Rushville" is uncertain. Hyde (1915, p. 772) suggested the possibility that these strata should be recognized as a member of the Logan formation, but later (1953, p. 131, 132) he included them in the Vinton member. Holden (1952, p. 60) gave the shale and limestone of the "Rushville" full member status. Flint (1951, p. 13, 14) and Fagadau (1952, p. 46-48) regarded the "Rushville" as a questionable member of the Logan formation. Fagadau (1952, p. 47, 48) studied a small collection of "Rushville" fossils and was able to conclude only that they are closely similar to a part of the ordinary Logan fauna.

The "Rushville" has been observed in a few outcrops in Perry County. No outcrops of "Rushville" are known in Fairfield County, and there is no evidence to show that the member is present.

MERAMEC SERIES

MAXVILLE LIMESTONE

The Maxville limestone was named by Andrews (1870, p. 80) for exposures near Maxville, Monday Creek Township, Perry County.

According to Flint (1951, p. 14) the Maxville in Perry County consists of gray to grayish-white limestone which weathers light gray or buff. It ranges in composition from sandy limestone to limestone with a calcium carbonate content of 95 per cent. Where the silica content is low, the limestone is dense to finely crystalline. Merrill (1950, p. 111) noted that in northern Hocking County the limestone is interbedded with calcareous shale containing limestone nodules.

The writer found no exposures of the Maxville limestone in Fairfield County. However, an outcrop of dense, gray limestone, which may be the Maxville, occurs in a ravine located just east of the Fairfield-Perry County line in the SW$\frac{1}{4}$ of section 26, Reading Township, Perry County. Morse (1910, p. 70, 71) described an occurrence of 2 or 3 feet of badly weathered Maxville limestone in an abandoned quarry which was probably located on the hilltop in the NE$\frac{1}{4}$ of section 15, Richland Township. It is not unlikely that a few patches of Maxville limestone may be present under cover in eastern Fairfield County.

According to Flint (1951, p. 15-18) the Maxville rests disconformably on the Vinton member or, in some cases, the "Rushville" member. Erosion of pre-Pottsville age has removed the limestone in most places, but where the Maxville is present it is overlain disconformably by the Pottsville group.

The Maxville is the youngest formation of Mississippian age in Ohio. Weller and others (1948, p. 160), on the basis of the trilobite assemblage of the limestone, indicated a Ste. Genevieve (Meramec) equivalence.

PENNSYLVANIAN SYSTEM

POTTSVILLE GROUP

Definition

The name "Pottsville" was first used by J. P. Lesley (1876, p. 221-227) for beds overlying the Mississippian Mauch Chunk and underlying the Lower Productive Coal Measures of Pennsylvania. According to Wilmarth (1938, p. 1721) the U. S. Geological Survey classifies the Pottsville as a formation except in areas where it is divided into two or more named and mapped major units. In the latter case the Pottsville is considered a group and the named units are considered formations. Recent (1961) usage by the Ohio Division of Geological Survey has been to call the named major units cyclothems rather than formations in the Pottsville.

In central Ohio the Pottsville includes all of the strata from the base of the Harrison ore to the top of the Tionesta cyclothem. In descending order, these are as follows:

Tionesta cyclothem
Bedford cyclothem
Upper Mercer cyclothem
Middle Mercer cyclothem
Flint Ridge cyclothem
Lower Mercer cyclothem
Vandusen cyclothem
Bear Run cyclothem
Quakertown cyclothem
Huckleberry cyclothem
Anthony cyclothem
Sharon cyclothem
Harrison "ore"

All of the units listed above are not necessarily present in any one locality. Neither Merrill (1950) in northern Hocking County nor Flint (1951) in Perry County recognized the Upper Mercer cyclothem. Flint (1951, p. 21) considered the occurrence of the Sharon cyclothem doubtful in Perry County.

Because of the relatively limited extent and poor exposure of the strata the writer was unable to identify with certainty any of the subdivisions of the Pottsville. It is not known definitely, therefore, how much of the Pottsville group is represented in Fairfield County.

Distribution

The distribution of the Pottsville group is shown on the geologic map (pl. 1). It caps some of the higher hills in eastern Berne Township, much of Rush Creek Township, and southeastern Richland Township.

Lithologic Character

The Pottsville strata in Fairfield County include sandstone, mudstone or shale, limestone, clay, and coal. Ordinarily only the coarse-grained sandstone at the base of the group is exposed. Exposures of clay, which is usually light gray and plastic, and coal are infrequent.

The sandstones of the Pottsville are commonly poorly sorted. They contain sand grains ranging in size from fine to coarse, and in a few localities to rounded quartz pebbles as large as half an inch in diameter. Ordinarily the sandstones are massive and friable, and commonly are ledge forming. Some soft, thin-bedded, fine-grained sandstones also occur, but they are slope forming and, therefore, are usually poorly exposed. The sandstones are markedly micaceous and ferruginous. Most of them are colored various shades of yellow and brown, with dark yellowish orange (10 YR 6/6) being most common. Extremes in color include white (N9) and pale red purple (5 RP 6/2). In the coarser grained sandstones the grains display glistening crystal faces which are the result of precipitation of secondary quartz. Plant fragments are abundant in some localities.

Mudstones or shales occur at a few localities. They are much like the sandstones in color, but they are usually very soft and tend to form slopes. The presence of carbonaceous matter and abundant mica serves to distinguish the mudstones and shales, as well as the Pottsville sandstones, from the underlying Mississippian rocks.

A single exposure of limestone was seen in the area. A few fragments of dark gray, fossiliferous limestone occur on the hill in the NE$\frac{1}{4}$ of section 24, Rush Creek Township. The limestone contains crinoid columnals, brachiopods, and fusulines. The fusulines belong to the species Fusulinella iowensis, which is characteristic of the Boggs, Lower Mercer, and Upper Mercer limestones of the Pottsville group (P. Smyth, personal communication). F. iowensis is unknown in the overlying Allegheny group.

Thickness

The thickness of the Pottsville group ranges from 0 to approximately 140 feet in Fairfield County. The group is thickest in eastern Rush Creek Township and, because of erosion, thins westward until it disappears in eastern Berne Township. The greatest measured thickness occurs in the SE$\frac{1}{4}$ of section 35, Rush Creek Township (O. G. S. 14586), where more than 70 feet of Pottsville strata was measured. The maximum thickness of the group, estimated from the geologic map (pl. 1), is approximately 140 feet. This exceptional thickness occurs in the NE$\frac{1}{4}$ of section 24, Rush Creek Township, on the hill where the fragments of fusuline-bearing limestone described above were found.

Stratigraphic Relations

The Pottsville group occurs at the base of the Pennsylvanian system and rests disconformably on strata of Mississippian age. Wherever the Mississippian-Pennsylvanian contact is exposed in Fairfield County, the Pottsville rests on the strata of the Vinton member of the Logan formation. The disconformable relationship is not apparent in any one outcrop. Evidence for the disconformity includes the total absence of strata of Chester age and the patchy distribution of the Maxville limestone of Meramec age. Disconformity may also be inferred from the variability in thickness of the Vinton member of the Logan formation.

Insufficient data prohibit a detailed knowledge of the configuration of the surface on which the Pottsville group was deposited. Consequently, it is shown on the geologic map (pl. 1) as a gently undulating surface. In detail, it may be considerably less regular than is indicated by the line showing the Logan-Pottsville contact.

In northern Hocking and Perry Counties the Mississippian-Pennsylvanian contact is overlain by the Harrison "ore", a thin bed which may consist of hematite, siderite, limonite, ferruginous cherty material, or ferruginous conglomerate (Flint, 1951, p. 20). The Harrison averages 1 foot in thickness in Perry County (Flint, 1951, pl. I) and ranges from less than an inch to more than 5 feet, with an average thickness of about 1 foot, in northern Hocking County (Merrill, 1950, p. 135, 136).

The writer was unable to recognize the Harrison in the few outcrops where the base of the Pennsylvanian system is exposed. Its persistence in Perry and Hocking Counties, however, is good reason to infer that it is probably present under cover in some parts of Fairfield County.

It may be inferred from the distribution of the Allegheny group in Perry County (Flint, 1951, pl. I) that the Allegheny is probably not represented in Fairfield County. If so, the Pottsville strata are the youngest Paleozoic rocks in Fairfield County, and they are overlain only by the deposits of the Quaternary system.

The upper limit of the Pottsville in Fairfield County is uncertain. The fossiliferous limestone fragments found in section 24, Rush Creek Township may represent the Boggs, Lower Mercer, or Upper Mercer limestones. According to Flint (1951, p. 31) the Boggs member does not consist of limestone in Perry County. In all probability, therefore, the limestone fragments represent either the Lower Mercer limestone (Middle Mercer cyclothem) or the Upper Mercer limestone (Bedford cyclothem). The bed from which the fragments were derived is not exposed, and the strata capping the hill are unknown.

QUATERNARY SYSTEM

The Quaternary deposits of Fairfield County are described in chapter 7 of this bulletin, pages 116-149.

Chapter 4

STRUCTURAL GEOLOGY

GENERAL STATEMENT

Fairfield County is located on the east flank of the Cincinnati arch. Consequently, the regional dip of the strata, as shown elsewhere in central Ohio, is approximately 25 to 30 feet per mile in an easterly direction. Local structural variations due to differential sedimentation and compaction, as well as the absence of a datum of sufficient areal extent, prohibit the presentation of a structure contour map which might be significant in regard to regional structure.

STRUCTURE CONTOUR MAPS

TOP OF BLACK HAND MEMBER

Structure contours were drawn on the surface of the Black Hand member of the Cuyahoga formation (fig. 31) in south-central Fairfield County, where the Cuyahoga-Logan contact is exposed. North and east of Berne Township the Cuyahoga lies below drainage, and in the western part of the county the overlying Logan formation has been removed by erosion.

A prominent structural high is apparent in eastern Madison Township, central and eastern Hocking Township, westernmost Berne Township, and the southeastern corner of Greenfield Township. The position of the high approximates the position of the axis of the Hocking Valley tongue. The high, which strikes north to north-northwest, trends obliquely to the regional strike, which is slightly east of north.

In western and central Berne Township the surface of the Cuyahoga formation is inclined to the east at a rate which commonly exceeds 60 feet per mile and locally exceeds 100 feet per mile. The scanty data available in the eastern part of the township indicate that the rate of descent decreases eastward.

The structural high which is developed on the crest of the Hocking Valley tongue consists of two distinct parts, a western high which trends northwest across central Hocking Township, and a more easterly high which trends north into southeastern Greenfield Township. The western high coincides approximately with the Bloom lobe of the Hocking Valley tongue, and the eastern high coincides with the Pleasant lobe. The dashed contours which define the highs in Hocking and Greenfield Townships have been drawn in spite of the almost total absence of Logan strata. Therefore, they indicate only the minimum elevation of the Black Hand surface prior to the erosion of the overlying strata. Because of the resistance of the Black Hand member to erosion, and also because of the obvious influence of the Black Hand member on the topography of nearby areas, the writer suspects that the

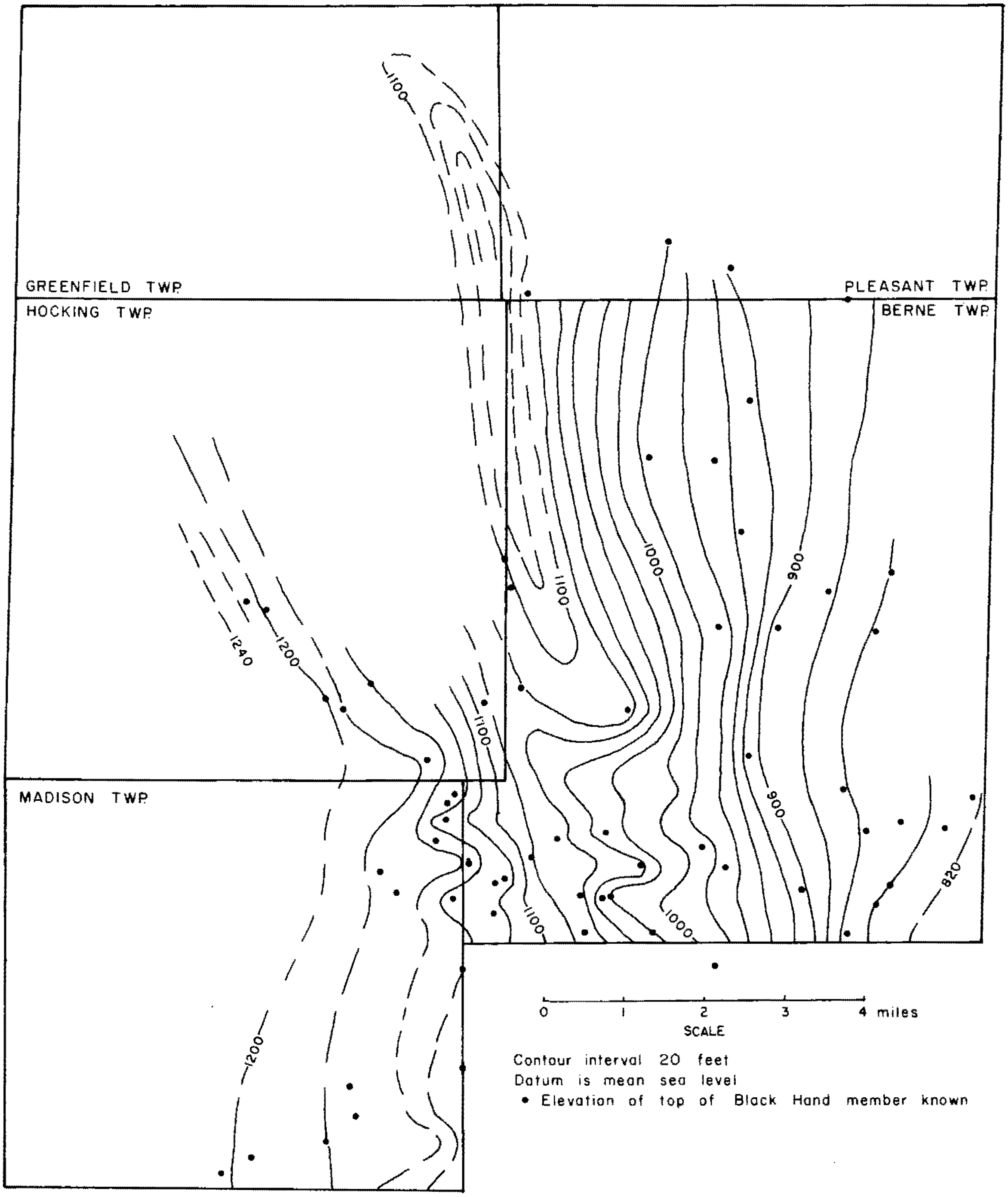


Figure 31. - Structure contour map of the surface of the Black Hand member in south-central Fairfield County.

dashed contours may represent approximately the original configuration of the Black Hand surface.

The anomalous structure of the Cuyahoga formation might have resulted from the warping of the strata into synclines and anticlines, from differential compaction during and following deposition, or from differences in thickness resulting from original deposition. It is difficult to prove conclusively that the Cuyahoga structure is not the result of gentle folding, but it seems unlikely. Hyde (1915, p. 676) noted that there is no evidence of similar structure in the underlying rocks. A similar conclusion was reached by Root (Root and others, 1961) in Knox County. Merrill (1950, p. 220) in northern Hocking County, found no correlation between the structure of the Cuyahoga surface and the structure of the younger Middle Kittanning coal. Furthermore, in Fairfield County the Berne and Byer members of the Logan formation tend to thicken eastward as the surface of the Cuyahoga descends, a relationship which is not suggestive of gentle warping.

An apparent correlation exists between the structure and the stratigraphy of the Cuyahoga formation. Outcrop and subsurface data indicate that the maximum thickness of the Black Hand sandstone is about 500 feet, in eastern Madison and Hocking Townships. At Mt. Pleasant, in the southwest corner of Pleasant Township, the Black Hand may be more than 400 feet thick. In western Berne Township the Black Hand sandstone intertongues with the fine-grained clastic rocks of the Raccoon member. Throughout most of Berne Township the Black Hand is probably represented only by the Sugargrove lobe, which is approximately 90 feet thick west of the Hocking River and thinner eastward. It is likely that it wedges out or grades laterally into the mudstones and siltstones of the Raccoon in eastern Berne Township or not far east of Berne Township. The surface of the Cuyahoga formation descends most rapidly in the zone of facies change between the Black Hand and Raccoon members. In easternmost Berne Township the change of facies from sandstone to fine-grained clastic rocks is complete or nearly complete, and the inclination of the Cuyahoga surface has diminished. In other words, the surface of the Cuyahoga formation is high where the sandstone facies (Black Hand member) reaches maximum thickness, and it is relatively low where the shaly facies (Raccoon member) reaches maximum thickness.

A similar relationship is suggested in the area between the Bloom and Pleasant lobes of the Hocking Valley tongue. Although the data are admittedly scanty, it seems likely that a sag exists in the Cuyahoga surface between the two Black Hand lobes. A few scattered outcrops in the vicinity of the Hocking-Greenfield Township boundary indicate that the shaly facies (Raccoon member) is present between the lobes of sandstone.

Hyde expressed the belief that the configuration of the Cuyahoga surface was the result of the conditions under which the sediments accumulated. In his words.... "the surface of the accumulation (of the Black Hand member) at any given time stood well above the mud floor of the adjacent shale facies..." (Hyde, 1915, p. 673). It seems reasonable to suppose that at times the surface of Black Hand accumulation stood above the surface of Raccoon accumulation. However, the writer believes that the structure of the Cuyahoga is largely the result of differential compaction. The greatest amount of compaction has occurred where the shaly facies of the Cuyahoga is thickest. Slight post-Pennsylvanian tilting in an easterly direction has increased the inclination of the Cuyahoga surface.

In northeastern Madison and southwestern Berne Townships, the area in which the most abundant data are available, the surface of the Black Hand is undulatory. The regularity of the contour lines elsewhere may reflect only the scarcity of data. If the possible occurrence of local warping of the strata is excluded from consideration, undulations of the Black Hand surface might be accounted for either by erosion of pre-Logan age or by differential compaction in the zone of Black Hand-Raccoon intertonguing. Neither of these agents may be excluded, and it is not unlikely that both were operative.

Evidence of a slight disconformity between the Cuyahoga and Logan formations in the area west of the Hocking River has been discussed previously (p. 73-75). If such an interpretation is correct, the irregularity of the Black Hand surface may be the result of slight dissection of the Hocking Valley tongue prior to the accumulation of the Logan sediments.

Stratigraphic considerations, however, suggest that the undulations may have resulted, at least in part, from differential compaction. A small synclinal sag is located west of the Hocking River along the valley of Brushy Fork in southernmost Berne Township. A tongue of the Raccoon, which crops out in a ravine immediately north of Brushy Fork (O. G. S. 14602), penetrates westward into the Hocking Valley tongue. Its northern extent is unknown, but the occurrence of 240 feet of Black Hand sandstone on the ridge to the south (O. G. S. 14595) shows that it wedges out rapidly in that direction. The ridge, which is located exactly at the Fairfield-Hocking County line, forms a local structural high on the Black Hand surface. The adjacent anticlinal sag is developed over a tongue of the shale facies. It seems probable that greater compaction in the locality of the Raccoon tongue has caused the local sag in the surface of the Black Hand. A similar relationship is suspected 2 miles to the north at Blue Valley, but the available data are insufficient for its confirmation.

TOP OF BYER MEMBER

Structure contours drawn on the Byer-Allensville contact (fig. 32) show that the configuration of the Byer surface reflects closely the configuration of the Black Hand surface. As indicated on the map, the control on which the contours are based is scanty. The contour lines, therefore, are highly generalized; they suggest far more structural regularity than may really exist.

Like the Black Hand surface, the Byer surface descends sharply eastward in western Berne Township, with the inclination decreasing to the east. In western Rush Creek Township the regional dip is approached. It is inferred from this that the eastern limit of the Sugargrove lobe of the underlying Black Hand lies near the Berne-Rush Creek Township line and that the facies change from Black Hand to Raccoon has been completed. In south-central Rush Creek Township the rate of descent of the Byer surface is less than the regional dip. Probably the presence of the Marion-Falls lobe of the Black Hand, which lies immediately to the south in Hocking County, is reflected here in the Byer surface.

In southeastern Pleasant and southwestern Richland Townships the contours approximate the regional dip as it has been shown in Perry County (Flint, 1951, pl. 1). An outcrop located in section 33, Pleasant Township (O. G. S. 14570) shows the transition from the Black Hand to the Raccoon member. Probably the Cuyahoga formation to the north, as well as to the east, of Berne Township consists solely of the Raccoon member, and the structure in these areas has not been influenced by differential compaction.

An anticlinal nose plunges gently toward the northeast in northeastern Berne Township. It may be that this reflects the northeastern limit of the Sugargrove lobe of the underlying Black Hand member.

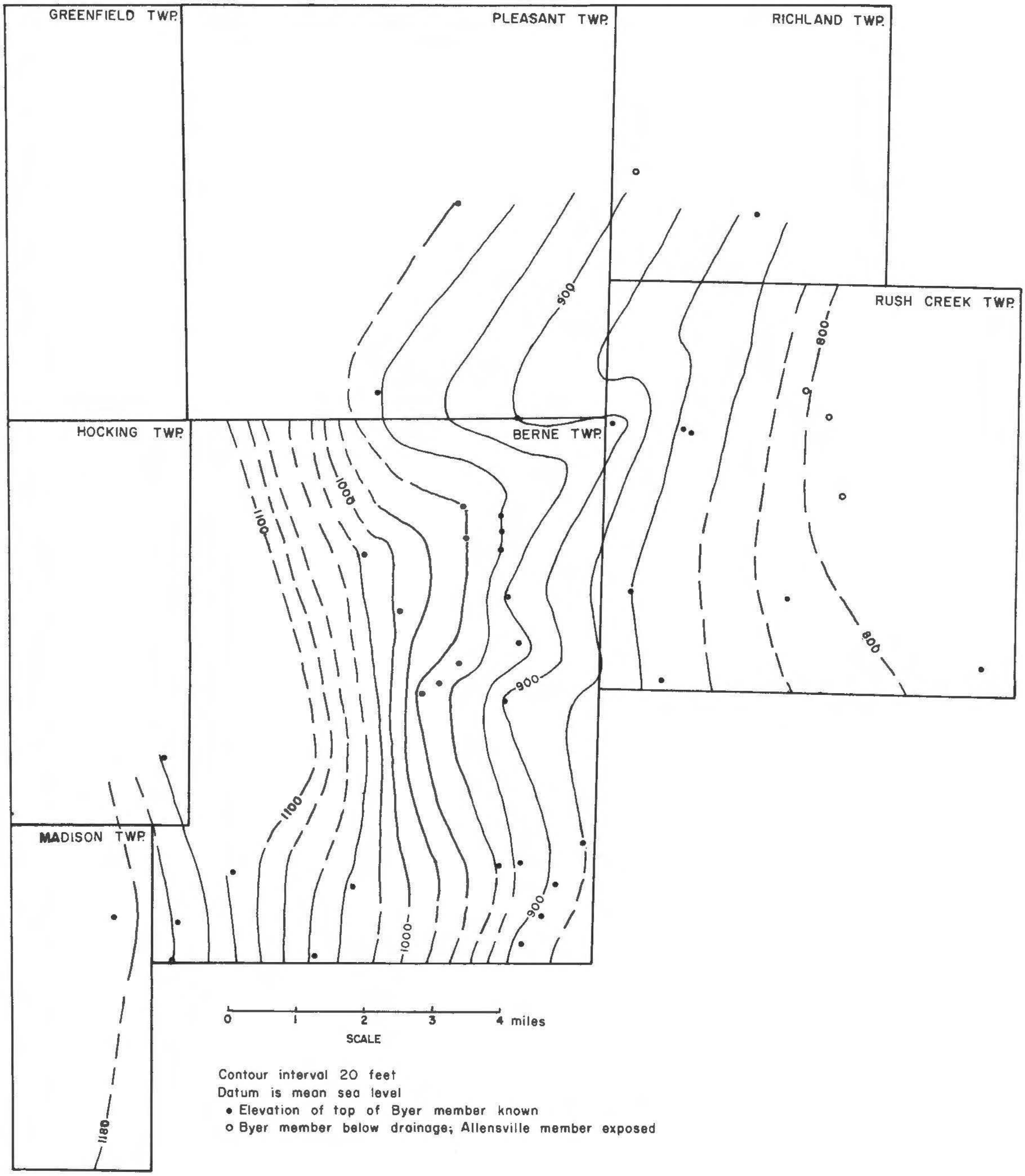


Figure 32. - Structure contour map of the surface of the Byer member in southern Fairfield County.

Chapter 5

EROSIONAL HISTORY

EROSION SURFACES

Following the deposition and deformation of the Paleozoic strata, an interval of about 180 million years (lasting from the beginning of the Mesozoic era to almost the end of the Cenozoic era) occurred during which little is known about the geologic events in Fairfield County. Presumably, at first, streams developed which flowed across the newly formed land and eroded valleys as streams do today. Certainly, a great deal of erosion is known to have taken place at this time throughout all Ohio. In Fairfield County, evidence from which the geologic history is interpreted consists of the present upland surface and the remains of a preglacial stream system which flowed northwest into the classic Teays drainage. The upland surface is believed by many to represent remnants of old erosion surfaces.

The near accordance of many of the summits in southern Fairfield County is strikingly shown in the view from some of the higher hilltops (fig. 33). A glance at the topographic map shows that the highest summits, at elevations of from 1240 to 1260 feet, occur in central and western Hocking Township. From here they descend toward the east at a rate such that the ridgetops immediately west of the

Figure 33. - Accordant ridges in south-central Fairfield County. View to the east from the top of Jacobs Ladder, in the NE$\frac{1}{4}$ of section 34, Hocking Township.

Hocking Valley rarely exceed 1100 feet. Immediately east of the Hocking Valley, in eastern Berne Township, the impression of accordance is diminished, in part at least, because of the absence of elongate, narrow, flat-topped ridges such as are typical west of the Hocking. The summits in this area range in elevation from 1000 to 1100 feet. Near the eastern border of Berne Township and particularly apparent in southern and eastern Rush Creek Township are broad, gently convex uplands which lie above the 1000-foot contour in western Rush Creek Township. They descend eastward so as to be approximately bounded by the 900-foot contour in eastern Rush Creek Township.

One other region, located in southwestern Madison Township and southeastern Clear Creek Township, merits consideration in a discussion of erosion surfaces. This area is largely covered by glacial drift, but rounded bedrock knobs barely project through the drift. Their summits range in elevation from about 1140 to 1200 feet above sea level.

Ver Steeg (1931, p. 186) identified two peneplains in the area of the Circleville, Lancaster, and Logan quadrangles. The lower summits, ranging from 1000 to 1100 feet in altitude, he assigned to the Lexington-Worthington peneplain and the higher summits, at altitudes of 1100 to 1200 feet, he considered as remnants of the Harrisburg peneplain. Cole (1934, p. 289-291) recognized only the Lexington-Worthington peneplain and considered the higher summits to be remnants of a divide on the Lexington-Worthington surface. In a physiographic study of the area immediately east and southeast of Fairfield County, Stout and Lamb (1938, p. 57-59) considered summits ranging in altitude from 1100 to 1200 feet to represent the Harrisburg surface. The lower summits, from 930 to 990 feet above sea level, were regarded as remnants of the Lexington-Worthington surface.

The writer believes that the various summit levels observed in southern Fairfield County do not necessarily reflect multiple peneplains. Each of the four regions described above is unique in topographic expression. Detailed geologic mapping indicates that each of these regions is also stratigraphically unique, and that the character of the topographic expression relates directly to the nature of the stratigraphy.

The accordant ridges shown in figure 33 are developed in the area that lies between the Hocking River and the west-facing escarpment of Black Hand sandstone in the western part of the county. Narrow flat-topped divides, frequently extending for several miles without interruption, are typical. The geologic map (pl. 1) shows that the accordant ridges are underlain by the ledge-forming Black Hand sandstone. Many of them are capped by thin remnants of the Logan formation. The complete stripping of the Logan formation has been impeded by the progressive decrease of upland gradients above the Black Hand ledges, as the higher beds of the Logan were removed from the upland surfaces. It seems reasonable to conclude that the surface represented by the accordant ridges west of the Hocking Valley is largely controlled by the configuration of the surface on which the Logan strata were deposited, that is, the surface of the Black Hand sandstone. The highland developed on the Black Hand sandstone extends to the northwest as an elongate spur which terminates at Chestnut Ridge in Bloom Township. West and north of central Hocking Township, the overlying Logan formation has been completely removed. No elongate, flat-topped ridges are present here, and the summits are not as obviously accordant as they are to the south and east. In this area the original Black Hand surface was higher than it was to the south and east, and so it has been obliterated by dissection and lowering of divides.

Immediately west of the highland developed on the Black Hand sandstone is an area of more subdued relief and lower summit levels, in southwestern Madison and southeastern Clear Creek Townships. Undoubtedly the subdued relief is due in part to the relatively thick accumulation of glacial drift. Stratigraphic evidence suggests, however, that glacial modification does not account entirely for the less rugged landscape, nor does it account for the lower elevations of the summits. The scattered outcrops indicate that a facies change from the massive, coarse-grained, ledge-forming sandstones of the Black Hand to fine-grained, bedded sandstones and shales has occurred. The finer grained facies is more easily eroded than its coarse-grained equivalent, and it tends to form slopes rather than flat-topped ledges.

In eastern Berne Township, the hill summits are lower than the ridges west of the Hocking River. They range in altitude from 1000 to 1100 feet above sea level and lack the obvious accordance displayed by the ridges to the west. The Black Hand sandstone is exposed in this area, but it occurs only in the lower parts of the valley walls.

The hilltops, capped by a thick sequence of soft Logan strata, are so small in area that it hardly seems likely that they could be interpreted as remnants of an older erosion surface. They seem rather to be remnants of uplands rapidly dissected and lowered following the removal of the overlying, more resistant Pottsville sandstones. Local irregularities in summit elevations may reflect minor deviations in stream density or in resistance of the strata present.

In easternmost Berne Township and most of southern and eastern Rush Creek Township, a pronounced topographic break separates steep valley walls from broad, gently convex uplands. The break in slope occurs at an elevation of about 1000 feet in western Rush Creek Township and descends eastward to about 900 feet above sea level near the Fairfield-Perry County line. Geologic mapping (pl. 1) shows that the steep valleys are carved in the easily eroded sandstones and siltstones of the Logan formation. The overlying basal sandstones of the Pottsville group are relatively resistant. They form a cuesta wherever the overlying, less resistant beds have been removed by erosion.

There seems to be little evidence within Fairfield County which points to the existence of more than one peneplain, and indeed, in the area of study the evidence for even one peneplain is inconclusive. Differences in summit elevations are closely related to lithologic differences in the underlying rocks. The surfaces represented by accordant summits reflect the degree of resistance to erosion of the strata supporting them as well as to the height of these strata above the streams (controlled by the structure of the underlying bedrock).

PRE-ILLINOIAN DRAINAGE

Contours drawn on the bedrock surface (pl. 1) outline the main pre-Illinoian drainage lines. Minor modifications have resulted from Illinoian and post-Illinoian erosion.

Two stages of pre-Illinoian drainage have been recognized in Ohio, but they are indistinguishable in Fairfield County. They have been described in detail by Stout, Ver Steeg, and Lamb (1943, p. 51-98). The earlier of the two stages is known as the Teays stage and was named for the Teays River, which flowed to the northwest across southwestern Ohio. All of the Fairfield County drainage in Teays time was controlled by tributaries of the Teays River. The advance of an ice sheet of probable pre-Illinoian age in northern Ohio ponded the Teays-stage drainage, causing the accumulation of lacustrine deposits (Minford silt) in the flooded valleys. As the waters spilled over previous divides, drainage reversals occurred and new channels were formed in some localities. Rapid entrenchment of the newly established (Deep Stage) drainage left the older valley floors, or remnants of them, stranded above the newer stream floors. The abandoned flood plains of the Teays system are recognized in many parts of the State as the Parker strath.

Neither the Minford silt nor the Parker strath can be identified in Fairfield County. If they are present, they are obscured by the thick glacial drift which fills the old valleys. Merrill (1953, p. 157) concluded that no evidence for two pre-Illinoian drainage stages is present in the Hocking Valley in Hocking County. Forsyth (Root and others, 1961, p. 121) reached the same conclusion about pre-Illinoian drainage in Knox County. A similar interpretation is appropriate in Fairfield County. The Deep Stage drainage, entirely controlled by the Newark River and its tributaries, followed the previously established Teays valleys in Fairfield County. Except for minor modifications, the bedrock surface shown on plate 1 is the Deep Stage surface as it existed when the Deep Stage erosion was terminated by the advance of Illinoian ice. The main drainage lines, as they existed at the end of Deep Stage time, are shown in figure 34.

DRAINAGE REVERSALS

HOCKING RIVER REVERSAL

The Hocking River heads near Greencastle, in Bloom Township, and flows southeast across Fairfield, Hocking, and Athens Counties to the Ohio River. Stout, Ver Steeg, and Lamb (1943) indicated that the ancestral Hocking River, called the Logan River (Teays time) or Lancaster River (Deep Stage time), headed in southern Hocking County and flowed northwest, emptying into the Groveport River (Teays) or Newark River (Deep Stage). Its original northwestern course is inferred from (1) widening of the Hocking Valley to the northwest, (2) the presence of barbed tributaries, and (3) the decrease in elevation of the bedrock floor of the river toward the northwest.

Kempton (1956) has mapped Illinoian terrace remnants in the Hocking Valley from Lancaster southeastward to southern Athens County. Elevations of surfaces on this terrace decrease to the southeast. Thus, it may be inferred that a southeast-flowing stream was established prior to the disappearance of Illinoian ice from the Hocking Valley watershed. The old divide, near the Hocking-Athens County line may have been breached when Illinoian ice ponded the Lancaster River. The presence of clay underlying Illinoian gravel in the Hocking Valley in Hocking County (Kempton, 1956, p. 27-30) supports the hypothesis that the divide was cut as a result of the damming of the Lancaster River.

CLEAR CREEK REVERSAL

Clear Creek heads in Amanda Township and flows south and east through Madison Township and northern Good Hope Township, Hocking County. It empties into the Hocking River in section 15, Good Hope Township.

A steep gorge, located just east of the Fairfield-Hocking County line, marks the position of an old divide that separated an eastward-flowing tributary of the Logan River (Teays system) or Lancaster River (Deep Stage) from a stream that flowed west through central Amanda Township and entered a tributary of the Teays River

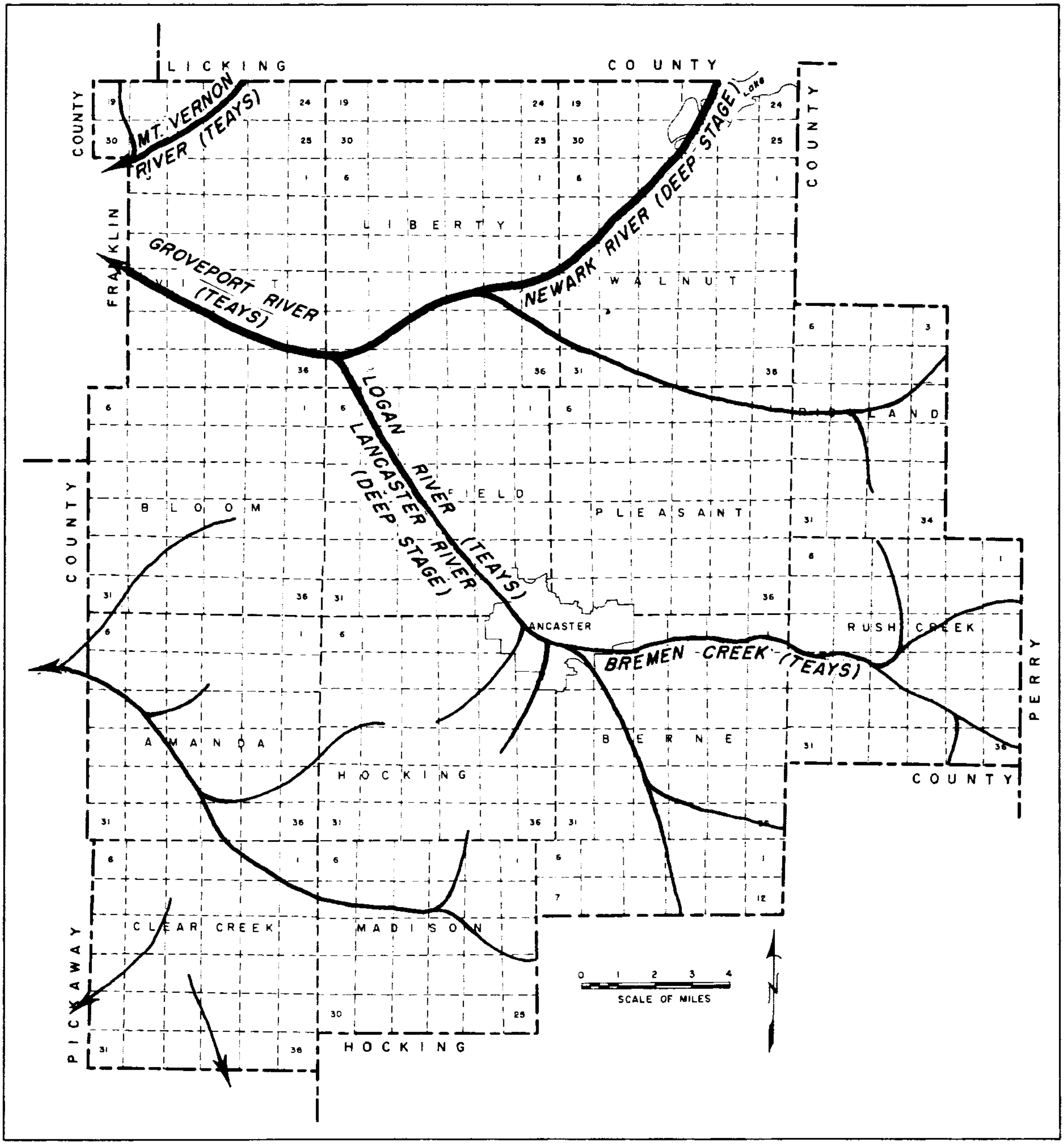


Figure 34. - Major lines of preglacial drainage in Fairfield County (modified from Stout, Ver Steeg, and Lamb, 1943; and Dove, 1960).

or its Deep Stage successor, the Newark River, in Pickaway County.

Because of the presence of Illinoian outwash in section 13, Madison Township, Conley (1956, p. 75) concludes that the drainage reversal occurred at the end of Teays time as a result of flooding associated with ponding of the Teays drainage. An alternate hypothesis is that the reversal occurred during Illinoian time. Melt water from the Illinoian ice sheet may have been ponded between the ice edge and the divide until the water level rose high enough to spill over the divide and erode the present gorge.

RUSH CREEK REVERSALS

Rush Creek heads in the vicinity of northern Richland Township and flows south through the gorge south of Rushville to the wide valley bottom south of Bremen, where Raccoon Run joins it from the west, and Little Rush Creek joins it from the east. From here it bears southeast and crosses the Hocking-Fairfield County line east of Geneva. In northern Marion Township, Hocking County, it swings 90 degrees and flows westward into southern Berne Township, where it empties into the Hocking River.

In Deep Stage time a stream which headed near Rushville flowed north to the large tributary of the Newark River that flowed westward across Richland Township. A second stream headed northeast and southeast of Bremen and flowed westward, discharging into the Lancaster River at Lancaster. Several miles to the south a third stream flowed west across northern Marion Township and emptied into the Lancaster River at Clark Crossing in south-central Berne Township.

In Wisconsin time the west-flowing drainage in northern Richland Township was dammed by ice, forming a lake in the vicinity of Oakthorpe. The lake waters spilled over the divide at Rushville and cut the deep Rushville gorge, establishing the present Rush Creek from Oakthorpe to Bremen. Wisconsin ice also blocked the mouth of the west-flowing stream which emptied at Lancaster (Conley, 1956, p. 92, 94). This valley was filled by a lake, whose overflow eroded the divide east of Geneva, finally establishing the southern part of the present Rush Creek.

ARNEY RUN REVERSAL

Arney Run heads in central Hocking Township and flows south through the steep gorge at Jacobs Ladder. It empties into Clear Creek northwest of Revenge in Madison Township.

Originally a stream flowed north from a divide located at Jacobs Ladder to Lancaster, where it emptied into the ancestral Hocking River. Wisconsin ice blocked the northward drainage, and a lake was formed north of Christmas Rocks in the vicinity of section 23, Hocking Township (Conley, 1956, p. 94). Overflow from the lake breached the divide at Jacobs Ladder, causing a permanent reversal of drainage and establishing the present Arney Run.

SIGNIFICANCE OF ORIGINAL EXTENT OF THE BLACK HAND

Since its deposition in Mississippian time, the Hocking Valley tongue of the Black Hand sandstone unquestionably has been reduced somewhat by erosion. However, the writer suspects that it never had a completely continuous occurrence, and that its present distribution (fig. 22) reflects its approximate original distribution. An important line of evidence in support of this hypothesis lies in an apparent relationship between the buried preglacial valleys and the distribution of the facies of the Cuyahoga formation. The large buried valley in the southern portion of Violet and Liberty Townships and its north-trending tributary between the Bloom and Pleasant lobes in Greenfield Township are particularly significant.

The occurrence of a few scattered outcrops of the easily eroded Raccoon member west of Lancaster in north-central Hocking and south-central Greenfield Townships suggest that the presence of the Raccoon between the lobes of Black Hand sandstone may account for the position of the mouth of the Logan (Teays system) River. An outcrop of the Raccoon in section 12, Greenfield Township, indicates that the deep preglacial valley north of the Pleasant lobe was cut into the Raccoon rather than the Black Hand. No field evidence is available to show that the valley of the Groveport River (Teays system) north of Chestnut Ridge was eroded into the Raccoon member rather than into the Black Hand. Nevertheless, it is likely that the valley would not have been located in its present position if the Bloom lobe had extended that far north.

There is little doubt that the Bloom and Pleasant lobes were modified by erosion as the Logan River deepened and widened its valley. The knobs of Black Hand sandstone in northeastern Hocking Township suggest that the Raccoon between the lobes may have been overlain by an appreciable thickness of Black Hand which was readily removed as the Logan River cut headward into the soft underlying Raccoon. The facies change from Raccoon to resistant Black Hand both east and west of the valley, however, prevented excessive modification of the valley walls. Eventually the river did cut through the Pleasant lobe at Lancaster and, in doing so, it probably carved a steep gorge. The spectacular cliff which forms the southwest face of Mt. Pleasant may be a remnant of the wall of the gorge.

There is some suggestion of a similar occurrence in the valley of Brushy Fork in southern Berne Township. The valley has been eroded into a Raccoon tongue which passes westward into the Black Hand and is overlain by Black Hand sandstone. In the south valley wall, in the SW$\frac{1}{4}$ of section 9, the Raccoon tongue is absent and its interval is occupied by the Black Hand. It is possible that the location of Brushy Fork was determined by the presence of the Raccoon tongue, or in other words, it is possible that the prominent spur which forms the south valley wall of Brushy Fork owes its existence to the fact that it consists entirely of Black Hand.

The western limit of the Hocking Valley tongue is marked by a west-facing escarpment which undoubtedly has undergone some eastward retreat due to erosion. Scattered outcrops in the southwestern part of the county, however, indicate that immediately west of the escarpment the lateral equivalents of the Black Hand are less resistant rocks (Raccoon member and Cuyahoga formation, undifferentiated), but it is not known exactly how far below the top of the Cuyahoga formation they lie. If the effects of differential compaction on the west flank of the Hocking Valley tongue are comparable to those on the east, these strata may not lie far below the uppermost Black Hand. In any case, it is not unreasonable to speculate that the escarpment is the slightly modified topographic expression of a facies change from resistant Black Hand in the east to its less resistant equivalents in the west.

Chapter 6

GEOLOGIC HISTORY

PRECAMBRIAN TIME

In central Ohio, unmetamorphosed sedimentary rocks of Paleozoic age rest unconformably on crystalline Precambrian rocks. Precambrian rocks are not exposed in Ohio, and no wells penetrate the Precambrian in Fairfield County. Some inferences about the Precambrian rocks of Fairfield County may be made, however, on the basis of samples from wells located in nearby counties. The nearest wells are the Vance well in Orange Township, Delaware County, and the Long well in Monroe Township, Pickaway County.

McCormick (1961, p. 46-48) studied cuttings from the Long well and recognized three rock types: marble, biotite gneiss, and gabbro. He concluded (1961, p. 48) that the marble and gneiss represent regionally metamorphosed sedimentary rocks which later were intruded by gabbro.

Cuttings from the Vance well were studied by Lamey (Stout and Lamey, 1940, p. 687-692). He suggested (1940, p. 692) that the gneiss complex represented by the samples was formed by the intrusion of granite into intermediate to basic igneous rock. Rubidium-strontium determinations on the Vance well cuttings indicate an age of 950 million years (M. N. Bass, personal communication cited in McCormick, 1961, p. 55). McCormick indicated the Grenville equivalence of these rocks and noted that the presence of marble is a point of similarity of these rocks to the Grenville series.

Rocks such as these are thought to form deep within belts of fold mountains. It may be inferred that such a mountain belt was in the process of formation about a billion years ago in central Ohio. The events which occurred after the mountain-building episode and prior to the deposition of the first Paleozoic strata are recorded by an unconformity. Erosion during an interval that was probably no longer than 500 million years (Kulp, 1961), and that may have been of shorter duration, reduced the mountain range to a surface of probable low relief and exposed the crystalline rocks at the mountain core. McCormick (1961, p. 56) indicated that the Precambrian surface descends from a depth of 2000 to 3000 feet in western Ohio to a depth of 8330 feet in Guernsey County. Data from scattered wells do not suggest relief of mountainous proportions, and much of the apparent relief undoubtedly resulted from differential subsidence during the Paleozoic era.

CAMBRIAN TO DEVONIAN PERIODS

Except for the uppermost part of the Ohio shale, which is of late Devonian or possible early Mississippian age, no rocks of pre-Mississippian age are exposed in Fairfield County. It is possible, however, to make some generalizations about the pre-Mississippian history on the basis of outcrops located outside the county and on the basis of oil and gas well data. Brief examination of such data shows that the area of study was inundated by the sea during parts of the Cambrian, Ordovician, Silurian, and Devonian periods. The strata deposited during this time consist largely of carbonates and shales, with a few sandstones. They thicken appreciably toward the east as a result of more rapid subsidence eastward in the Appalachian geosyncline.

During early and medial Cambrian time Fairfield County was probably a land area. Cuttings from deep wells in Pickaway County (Long well) and Delaware County (Vance well, described by Stout and Lamey, 1940) show that the Precambrian basement is immediately overlain by Upper Cambrian strata. The advance of the early Paleozoic sea from the south, and probably the east as well, is indicated by the fact that Trenton and sub-Trenton beds successively overlap the southward-plunging crest of the Cincinnati arch (Lockett, 1947, p. 433). Throughout most of the remainder of early Paleozoic time, the central Ohio area subsided and received marine sediments, probably derived in large part from the east. Occasional withdrawals of the sea and the ensuing interruptions in sedimentation are recorded by disconformities.

In late Devonian time the Ohio shale, which includes the oldest exposed strata in Fairfield County, was deposited. The origin of the Ohio shale, as well as the origin of similar and possibly contiguous black shales distributed over much of North America, has long been a point of controversy. There are two schools of thought on the origin of mid-Paleozoic bituminous shales. One maintains that the shales were formed in relatively deep quiet water below wave base, and the second argues that the black shales were formed in the shallow waters of a transgressive sea.

Rich (1951) suggested that the bituminous shales were deposited well below wave base in the deeper, unaerated portion of an extensive marine basin. He believed that the delicate laminae composed of very fine grained material could neither have been formed nor preserved if waves or currents had been active during deposition.

Conant (1953) considered the Chattanooga shale to be a shallow-water deposit. Among the criteria he listed for shallow-water deposition are perfection of lamination, high degree of sorting, and the fact that the shale lies directly on an unconformity. He noted that the shale consists of silt- and clay-sized particles of quartz, clay, mica, pyrite, and considerable organic matter. The presence of clastic particles as coarse as silt and their sorting into paper-thin laminae supports the hypothesis that currents were active.

A number of writers have concluded that the mid-Paleozoic black shales are transgressive to the south (Grabau, 1906; Klepser, 1937; Stockdale, 1939; Campbell, 1946). Hass (1956, p. 18), however, in a study of the Chattanooga in Tennessee, used a bentonite bed as a time line and concluded that the Chattanooga is not a transgressive, near-shore deposit. This is an agreement with Rich's (1951) hypothesis that the black shales accumulated in deep water and that the disconformity is partly the result of nondeposition during part of late Devonian time.

The black color of the shale is probably due in part to the presence of abundant finely divided plant remains. Hoover (1960, p. 33) noted that the black shales contain from 10 to 20 percent carbonaceous matter. The identifiable plant remains of the Ohio shale consist largely of the spores of terrestrial plants and trunks of Callixylon newberryi. Seaweed remains cover the bedding surfaces in some places (Hoover, 1960, p. 33). According to J. M. Schopf (1961, personal communication), a substantial portion of the carbonaceous matter of the Ohio shale was probably derived from the degradation of marine algae.

It is certain that the Ohio shale formed in the absence of all but the finest clastic sediments. The source areas of the terrigenous components of the shales were either very low lying or far enough removed from the area of accumulation to prevent the influx of sand. The waters of the basin floor must have been deficient in oxygen in order to prevent the total decomposition of carbonaceous matter. Because of the toxicity of the bottom waters, marine scavengers were absent. Organic detritus accumulated rapidly enough to establish and maintain reducing conditions, which were capable of removing any free oxygen introduced into the foul environment.

Neither bottom currents of cold oxygenated water, which replenish the oxygen supply of modern ocean deeps (Richards, 1957, p. 197), nor seasonal overturn was effective in oxygenating the bottom waters of the late Devonian epeiric sea. Perhaps climatic conditions were more equable than they are now. According to Moore, "The similarity of Devonian invertebrate faunas from high- and low-latitude belts indicates that an equable climate of fairly warm and humid type prevailed over much of the globe" (Moore, 1958, p. 202).

Turbulence, due either to wave or current action, must have been great enough to permit the tranportation and sorting of clay- and silt-sized particles. The turbulence was not sufficient, however, to cause extensive disruption of the stratification of the bottom water layers. Such disruption presumably would have resulted in the mixing of the higher oxygenated waters with the foul waters below, and anaerobic conditions could not have been maintained.

MISSISSIPPIAN PERIOD

BEDFORD TIME

Reconstruction of the history of Bedford time would be difficult on the basis of the Fairfield County data alone. The writer's observations agree closely with those of Pepper and others (1954), who undertook a detailed regional study of the Bedford and Berea formations. The historical interpretation offered by Pepper and his associates fits the available facts admirably, and the writer can do little more than summarize those aspects of it which pertain to Fairfield County.

Deposition of the Ohio shale was terminated in early Mississippian time by uplift in Ontario which resulted in an influx of fresh, muddy water into the Ohio Bay. The change in regimen caused a cleansing of the foul bottom waters of Ohio time, and a marine invertebrate fauna developed. Subsidence did not keep pace with sedimentation, and a delta complex advanced southward into the basin. The area of study lies in the west-central portion of the deltaic mass (fig. 5).

The fluvial origin of the subaerial portion of the delta is suggested by the occurrence of sinuous sand-filled channels, which are found as far south as Athens County. The channel sands, which are not known in Fairfield County, lie within the red portion of the delta complex.

The sediments of the Bedford were interpreted as having been derived from the erosion of red soil which developed in Ontario during the late Devonian. Where the red sediments were deposited on the subaerial portion of the delta, they retained their red color. Deposition below sea level at the delta front, however, reduced the hematitic pigment, producing the gray shale which occurs at the base of the Bedford in Fairfield County.

Diversion of the Ontario River in late Bedford time terminated the growth of the delta in central and southern Ohio. Swamps developed on the delta surface, and it may have subsided slightly below the level of the Ohio Bay. Reduction of ferric iron in the uppermost beds produced the thin gray zone at the top of the formation.

BEREA TIME

Uplift in late Bedford time rejuvenated the Ontario River. Deep channels, which in some places reach the Cleveland shale, were eroded in northern Ohio. Minor channeling occurred in Bloom Township, Fairfield County. The irregularity in thickness recorded in well records elsewhere in the county may also be indicative of channeling. The channeling was terminated by a northward advance of the strand line. Portions of the channel sands were reworked and spread out as a continuous thin sheet of sand across Fairfield County.

Oscillation ripple marks trending N. 70° W. were noted in several localities in Bloom Township. Hyde (1911) noted the occurrence of oscillation ripple marks with an average trend of N. 60° W. in a large area in central and southern Ohio. He concluded that the ripple marks were controlled by a northwest-trending land mass in eastern Kentucky.

Bucher (1919, p. 249-269) and Pepper and others (1954, p. 81-88) concluded that the ripple marks were controlled not by a northwest-trending shoreline or shoal, but by offshore winds moving over a large expanse of water to the southwest.

SUNBURY TIME

The submergence of the Bedford-Berea delta complex ended the introduction of coarse detritus into the area, and a toxic, black mud environment was established behind the northward-advancing shoreline. Abundant sand mixed with the black shale in the lowest inch of the Sunbury is indicative of turbulence and slight reworking of the underlying sand during the initial stages of Sunbury deposition.

CUYAHOGA TIME

RACCOON DEPOSITION

The introduction of gray mud and silt into the Ohio Bay initiated the deposition of the Raccoon member and brought to a close the delicately balanced conditions of Sunbury sedimentation.

Few data indicative of the source direction are available in Fairfield County. However, Szmuc (1957, p. 213-215) found evidence of an eastern source for the fine-grained clastic rocks of the Cuyahoga formation in northern Ohio. Pepper and others (1954, p. 91) suggested that the Cuyahoga muds, silts, and sands spread into Ohio as a result of upwarping in West Virginia. Pelletier (1958, fig. 16) determined the position of a northeast-southwest-trending shoreline in the lower Mississippian Pocono formation in western Pennsylvania and West Virginia. To the east and southeast, fluvial sandstones and conglomerates accumulated. The Raccoon probably is an offshore facies equivalent of the Pocono formation.

In the lower part of the Raccoon, massive siltstones alternate with shales. The lower contacts of the siltstones are sharp, and the upper contacts are gradational. According to Rich (1951a, p. 7) bedding of this type is developed just below wave base in offshore areas. Storms in the shallower, near-shore areas roil the water, making it turbid. Silt and clay are carried in suspension out to deeper water, where the silt settles rapidly to form a siltstone layer. The clay-sized particles settle more slowly to form the overlying shale beds. Each storm is recorded by the deposition of a siltstone bed.

Some of the siltstone beds seem too thick to be the result of a single storm. The nature of the bedding suggests, however, that the sediment was transported by density currents. Ripple marks on a siltstone bed in the stream near Lithopolis indicate that currents were active. The current flowed N. 75° W., a direction compatible with the hypothesis of an eastern source.

Thin siltstones occur in the Raccoon on the east flank of the Hocking Valley tongue of the Black Hand member, but west of the Hocking Valley tongue, near Tarlton, interbedded siltstones are absent from the Raccoon. The barrier of Black Hand sand apparently blocked all westward movement of silt. According to this hypothesis, the silt must have been derived from an eastern source. The mudstones are interbedded with thin, fine- to medium grained sandstones which probably represent intertonguing with the Cuyahoga formation, undifferentiated. The origin of these sandstones is related to the origin of the Black Hand and is discussed therewith.

BLACK HAND DEPOSITION

After Raccoon sedimentation had become well established, a large quantity of coarse sand and gravel was introduced into the marine basin to form the Black Hand member. The peculiar distribution of the Black Hand, critical in any attempt to determine its origin, is shown in figures 9 and 22. Hicks (1878) studied the Black Hand in Licking County and commented that its structure in that limited area suggested deposition on a beach. Hyde (1915) suggested that the sandstones might have accumulated as beaches, spits, and bars, but he favored a hypothesis of deltaic origin. Holden (1942) favored a deltaic origin, but Ver Steeg (1947) believed that the Black Hand could have accumulated only as beaches, spits, and bars. Root (Root and others, 1961) strongly favored the deltaic hypothesis. The writer believes that the deltaic hypothesis best fits the available data.

The Black Hand sandstone in Fairfield County appears to be barren of fossils. This is to be expected in such a coarse-grained, permeable rock, as any shell fragments which might have been buried would have been readily dissolved after deposition of the sand. In spite of the apparent absence of fossils, the writer believes the Black Hand to be largely of marine origin. Fine-grained sandstones (Cuyahoga formation, undifferentiated) are facies equivalents of the Black Hand. They contain well-preserved marine fossils and are located adjacent to the Hocking Valley tongue and also immediately beneath the Sugargrove lobe. A few marine fossils have been found in the stratigraphically equivalent Raccoon member, and marine fossils have been reported in the Black Hand elsewhere in the State (Fagadau, 1952, p. 29; Szmuc, 1957, p. 90).

It seems probable that the immediate source of the Black Hand lay to the southeast. Paleogeographic considerations do not favor a southern, southwestern, western, or northwestern source. The occurrence of the fine-grained marine clastic rocks in eastern Fairfield County precludes a direct eastern source for the Hocking Valley tongue. The northward bifurcation and the probable northward termination of the Hocking Valley tongue militate against an hypothesis of a northern source. Ver Steeg (1947, p. 726) suggested that the sediments of the Black Hand may have been transported from the Canadian Shield by waves and currents and later reworked and shifted westward to form the Black Hand sandstone.

The terrestrially deposited sandstones and conglomerates of the Pocono group in Pennsylvania, Maryland, and West Virginia (Stose and Swartz, 1912; Reger, 1926; Butts, 1940; Pelletier, 1958) are in part equivalent in age and appear to be lithologically similar to the Black Hand. Hyde (1915, p. 769-771) suggested the Pocono of the Maryland-Pennsylvania-West Virginia area as the probable source of the Black Hand. It is likely that the Pocono group, if not the actual source of the Black Hand, is genetically related to it. Pelletier (1958) concluded that the sediments of the Pocono group in Pennsylvania and Maryland were derived from a highland area lying to the southeast near the present Atlantic coast. It does not seem unlikely that the Black Hand was derived from an Appalachian source. The trend of the mass of Black Hand sandstone indicates that this source lay to the south-southeast.

Delta hypothesis of deposition. - Hyde (1915, p. 765-769) believed that the Black Hand of the Hocking Valley and Toboso areas represents the seaward fringes of a delta building north-northwest into the early Mississippian sea. He suggested (1915, p. 673) that the inclined beds may correspond to the foreset beds of a delta, and that the overlying horizontal beds may correspond to the topset beds.

The distribution of the Black Hand sandstone in Ohio (fig. 9) and its relationship to the surrounding shale facies of the Cuyahoga formation are suggestive of a birdfoot delta like the one presently forming at the mouth of the Mississippi River (fig. 35). Recent studies of sedimentation on the Mississippi delta (Fisk and others, 1954; Scruton, 1955; Bates, 1953) are extensively drawn upon in the following discussion.

By analogy with the Mississippi delta, the tongues of Black Hand sandstone represent the distributary channels of the Black Hand delta. They were built forward just below sea level by the progradation of distributary mouth bars. During flood stage a torrent of fresh water flowed north-northwest through the Hocking Valley distributary, scouring the channel bottom of detritus which had accumulated at low water and carrying a bedload of sand and gravel. As it reached the mouth of the distributary, and later of the Bloom and Pleasant distributaries, the fresh water was forced to rise and thin over the denser salt waters of the open marine basin. Consequently the velocity of the flood waters was reduced, and the sediment load was deposited immediately beyond the mouth of the distributary channel. The fine clastic rocks of the Raccoon, which surround and underlie the Hocking Valley tongue, were deposited as the interdistributary trough facies and the pro-delta facies of the Black Hand delta complex.

West of the Hocking Valley tongue, and also on the west flank of the Pleasant lobe are the fine-grained sandstones denoted as Cuyahoga formation, undifferentiated. In the southwestern part of the county these sandstones interfinger with the dark mudstones of the Raccoon. Flow casts on their undersurfaces indicate scouring of the underlying mud by the sand-bearing currents. The fine-grained

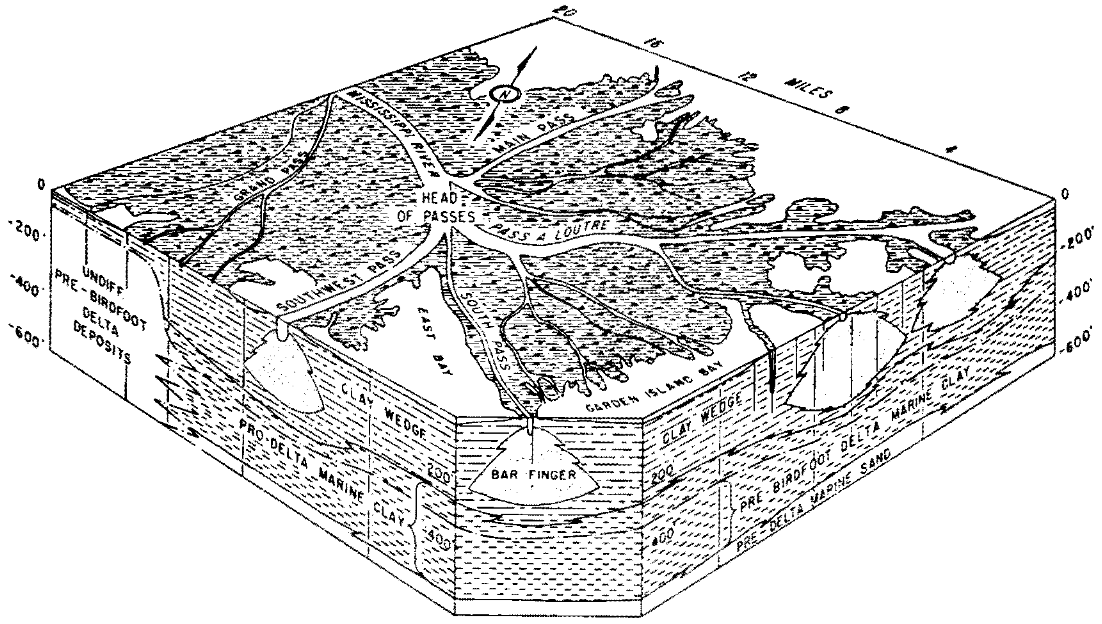


Figure 35. - Block diagram of the birdfoot delta of the Mississippi River (after Fisk and others, 1954, fig. 1; reproduced by permission of H. N. Fisk).

sandstones are of probable marine origin. Hyde (1915, p. 672) has noted the occurrence of marine fossils in sandstones transitional between the Black Hand and the shales (Raccoon of this report) of the Cuyahoga in the Hocking-Ross-Vinton County region, and marine fossils have been found in similar sandstones elsewhere in Fairfield County. According to the delta hypothesis, the fine-grained sandstones were deposited on the lateral margins of the distributary mouth bars beyond the reach of the coarser grained clastic sediments. From time to time turbidity currents spread thin sheets of fine-grained sand westward into the adjacent interdistributary trough.

Similar fine-grained sandstones have been found east of the Hocking Valley tongue in Fairfield County only beneath the Sugargrove lobe. This lobe and the underlying fine-grained sandstones appear to represent a modification of the Black Hand delta and will be considered shortly. Because of lack of exposure it is not known that the fine-grained sandstones are absent everywhere on the east flank of the Hocking Valley tongue (except below the Sugargrove lobe). However, the lower lobe of Black Hand sandstone, exposed near the Hocking-Fairfield County line just west of the Hocking River, is in sharp contact with the enclosing fine-grained clastic rocks of the Raccoon. It, as well as a similar sandstone lobe exposed at the base of the north wall of Blue Valley, is more like the sandstone of the Sugargrove lobe than that of the interior of the Hocking Valley tongue. It is massive and more uniform in texture than the sandstones deep in the Black Hand to the west, and it contains no clay galls. A possible explanation is that wave action reworked the sediments of the eastern flank of the Hocking Valley distributary bar, winnowing out silt and clay and leaving a deposit of massive sand. The wave action must have been more gentle that that of modern open coasts. It did not interfere appreciably with the seaward growth of the distributary. The presence of somewhat quieter conditions west of the Hocking Valley tongue may be inferred from the gradation from Black Hand to Raccoon and from the presence of sideritic concretions in the mudstones of the Raccoon.

A great thickness of the Black Hand sandstone suggests that the delta subsided as it grew, either because of compaction, or subsidence of the basin floor, or both. Late in the episode of Black Hand deposition, either the balance between influx of detritus and subsidence of the basin was disturbed, or the influence of wave action became more significant in controlling the shape of the delta.

The change of regimen resulted in the lateral spread of thick sheets of coarse sand. One sand sheet has been preserved as the Sugargrove lobe. Outcrops of Black Hand sandstone at Beck's Knob in section 10, Hocking Township, and in the SE$\frac{1}{4}$ of section 30, Madison Township, suggest that similar sheets of sand, which have been almost completely removed by subsequent erosion, were formed west of the Hocking Valley tongue and between the Bloom and Pleasant lobes.

The effects of waves and currents in the deposition of the Sugargrove lobe are strikingly shown by the occurrence of irregular crossbedding and conspicuous scours in the lobe and in its stratigraphic equivalents over the axis of the Hocking Valley tongue. Probably because of winnowing by wave action, these sandstones contain little clay, silt, or fine sand and no clay galls or clay layers. The great variability in bedding shown by the lower sandstones is absent. Fine-grained sand (Cuyahoga formation, undifferentiated), probably winnowed from the accumulating mass of coarser detritus, was spread out in front of and overlapped by the advancing front of the coarser sand.

Wave action did not completely dominate the shaping of the upper part of the Hocking Valley tongue; it merely modified the shape by lateral shifting of sand. The Hocking Valley distributary system probably continued as the source of Black Hand detritus. The evidence for this supposition is the fact that the largest pebbles and the greatest quantity of pebbles occur west of the Hocking River over the axis of the Hocking Valley tongue. East of the Hocking River the Black Hand of the Sugargrove lobe appears to be devoid of pebbles except in the southernmost part of the area. Apparently the currents or waves which spread the sand laterally were generally ineffective in moving the coarsest detritus supplied by the distributary channels.

The northeast-dipping beds of the Hocking Valley tongue remain to be explained. They occur in the upper part of the Black Hand in the axial portion of the Hocking Valley tongue, and they appear to be locally rather than universally formed. They may represent foreshore deposits on northeast-facing beaches. Such an origin was suggested by Hicks (1878) and Ver Steeg (1947). No conclusive evidence of beach formation has been recognized in Fairfield County. However, the Black Hand surface may have been exposed to erosion at least over the axial portions of the Hocking Valley tongue prior to the deposition of the Logan formation. Although such an event might have been the result of a slight sea-level change, a beach would have presented a surface readymade for attack by subaerial erosion. Additional evidence that beaches may have developed is in the occurrence of beach cusps in Benton Township, Hocking County (Hall, 1951, p. 38). It is not unlikely that clogging of the distributary channels contributed to the lateral spreading of the Black Hand sand, the building of beaches above sea level, and eventual abandonment of the Hocking Valley distributary system. In a situation such as this, where sand is deposited as a result of lateral shifting and overflowing of clogged distributary channels on a delta front which is being modified by wave action, the distinction between slopes of beach deposits and slopes of deltaic foreset beds is not a clear one.

Several features of the Black Hand not mentioned in the above discussion are readily explained according to the delta hypothesis. Characteristic of the sands interpreted as distributary bar deposits are abundant clay galls and clay pebble conglomerates. The latter, with their randomly oriented clay galls, are suggestive of the highly turbulent conditions which prevailed in the distributary channel during flood stage. Dunbar and Rodgers (1957, p. 64) indicated that clay galls commonly form where meandering streams undercut flood-plain deposits, and they expressed the belief that clay galls should be an excellent criterion of fluvial deposition. Although the writer is skeptical about the necessity of fluvial deposition to explain the presence of clay galls, he agrees that they could probably have been neither formed nor preserved in a zone of wave action.

A second feature of the Black Hand which supports the delta hypothesis is the common occurrence of red sandstone in the distributary bar sands. Finely divided hematite, the source of the red color, is thought to be rapidly reduced to gray ferrous oxide upon introduction to the slightly reducing conditions of normal marine waters. The bedload of the distributaries of the Mississippi delta is transported by fresh water during flood stage to the crests of the distributary mouth bars and dumped on the seaward side of the bars (Bates, 1953, p. 2140). Rapid burial should permit only extremely limited contact with sea water for most of the bar sands. If Black Hand deposition occurred under conditions similar to those of the Mississippi delta, the sands of the Black Hand distributaries probably suffered little contact with sea water and the preservation of the red color is to be expected. Red sediments are common in the Pocono group. The origin of the red sandstone is, therefore, easily explained if the Pocono is regarded as the source of the Black Hand or if the Pocono and Black Hand are regarded as sharing a common source.

The absence of marine fossils may be explained, at least in part, by the deltaic hypothesis. During approximately a third of each year the distributaries of the Mississippi delta are completely filled with seaward-moving fresh water and sediment. During the remainder of the year, however, the discharge is low enough so that fresh water does not fill the channels to capacity and dense salt water creeps upstream along the channel bottoms for distances as great as 125 miles (Scruton, 1955, p. 26, 27). The rapid change from marine to fresh water conditions in the distributary channels and on the distributary mouth bars does not favor the development of an extensive fauna.

Objections to the delta hypothesis. - The delta hypothesis is not entirely free of objections. The coarseness of the Black Hand sandstone has been pointed out as an objection to the delta hypothesis because modern deltas building seaward consist of much finer material. Little material coarser than fine sand is being deposited on the present Mississippi delta. However, modern marine deltas are supplied by rivers whose channels have recently been aggraded as a result of a worldwide rise of sea level as the last ice sheet retreated. Because of reduced gradient and probably reduced discharge the modern Mississippi is unable to deliver coarse-grained clastic sediments to its present delta. There is no reason to suspect that the history of the Black Hand was complicated by major sea-level changes, and it may not be necessary to eliminate the delta hypothesis from consideration because of the coarseness of grain size.

Rapid changes from massive to thin bedding, as well as rapid variation in grain size, such as might be expected in a channel situation, are typical of the lower part of the Black Hand. However, no deposits of undoubted natural levee or marsh origin were recognized. This is not fatal to the delta hypothesis. On the Mississippi delta the natural levees and marshes constitute a relatively small part of the total deltaic mass; they comprise the only subaerial portions of the delta. Spreading of the upper sands of the delta by waves and currents during the later stages of Black Hand accumulation may well have obliterated the natural levees. The marshes of the Mississippi delta lie just beyond the natural levees on the fringes of the interdistributary troughs, and the marsh deposits are similar to those of the troughs. If such deposits are present in Fairfield County, and if they are exposed, which is unlikely, they have not been distinguished in the gross process of field mapping and are included as a part of the Raccoon.

Lack of success in tracing the delta in southern Ohio precludes unequivocal acceptance of the delta hypothesis. The Black Hand passes beneath rocks of Pennsylvanian age not far south of Fairfield County. Ver Steeg (1947) was able to trace it for a short distance in the subsurface, but no obvious connection with a land area to the southeast has been found. The writer suspects that careful study of present and future subsurface data in southeastern Ohio will permit the tracing of the Black Hand to the southeast, provided that it has not been removed by pre-Pennsylvanian erosion.

Bar, beach, and spit hypothesis. - Ver Steeg (1947, p. 724) considered the Black Hand sandstone to be the result of deposition in the form of bars, beaches, and spits, deposited either simultaneously or in succession from east to west. Hyde (1915, p. 767) suggested that the structures are like those to be expected in bars or spits, but he did not pursue this line of thought further because he felt it was impossible for two bars of this nature to be developed parallel to each other simultaneously.

Several serious objections may be raised to the beach, bar, and spit hypothesis of Ver Steeg. He suggested (Ver Steeg, 1947, p. 726) that the material may have been carried originally from the north by waves and currents to a site in eastern Ohio and adjacent states and subsequently shifted westward to form bars, spits, beaches, and deltas in central Ohio. In the cross sections which he described (Ver Steeg, 1947, p. 719-722), however, the sandstones of central Ohio are separated from their proposed source in eastern Ohio by a shaly facies. The difficulty involved in transporting sand and gravel from eastern to central Ohio across an area in which shale is accumulating is great enough to cast grave doubt on the hypothesis.

Bars are generally coastal features, and the presence of a nearby coastline is questionable. Pelletier (1958, fig. 16) indicated that the Pocono strandline lay well to the east of the Ohio-Pennsylvania border. Its position is generalized, of course, and the shoreline may have been somewhat farther west during Black Hand deposition. That it was far enough west to have directly influenced Black Hand deposition is certainly questionable.

The writer, furthermore, questions the ability of marine agents alone to distribute the coarse-grained clastic sediments of the Black Hand in the shallow, early Mississippian epeiric sea. In view of the difficulties apparently involved in an hypothesis involving bar or spit origin, and in view of the apparent ease with which the delta hypothesis accounts for the features of the Black Hand, the writer subscribes to the delta hypothesis.

LOGAN TIME

BERNE DEPOSITION

Upon the establishment of a beach on the delta surface, the Hocking Valley distributary system was abandoned, and the supply of coarse detritus was cut off. For a brief interval the crest of the beach was exposed to subaerial erosion. Although the interval must have been brief, it was sufficiently long to permit the spread of sand and gravel of the Berne member across the low marine areas which overlay the old interdistributary troughs.

Several lines of evidence support this hypothesis. In both composition and grain size the Berne is similar to the underlying Black Hand. The upper surface of the Black Hand on the crest of the Hocking Valley tongue is marked by channel-like irregularities (fig. 31). Some of the irregularities may be accounted for by differential compaction. However, the depressions in the Black Hand surface along the western boundary of Berne Township contain unusual thicknesses of the Berne member, and there is little apparent reason to attribute them to differential compaction. They may represent stream channels. Between them the Berne is generally thin, or in some places it may be absent. Where it is present between the channels on the crest of the Hocking Valley tongue it commonly consists of a concentrate of gravel in a matrix of sand and is suggestive of a lag left on the Black Hand surface. Some reworking and spreading of the lag may have accompanied the subsequent advance of the sea over the delta surface.

Further evidence as to the conditions of deposition of the Berne may be found in the occurrence of marine fossils east of the crest of the Hocking Valley tongue, the greater thickness and increased amount of fine-grained sandstone east of the axial portion of the Hocking Valley tongue, and the gradational Cuyahoga-Logan contact reported by Merrill (1950, p. 87). These features are consistent with the hypothesis that the Berne member in the Fairfield County area was derived by the erosion of the crest of the Hocking Valley tongue and spread by streams, currents, and waves into a shallow marine basin lying immediately east of the crest of the Black Hand delta.

A slightly different mode of origin was proposed by Hyde.

> The underlying conglomerates were the source of material in this opening episode. This was probably a submergence of the sea floor and deepening of the waters, with complete cessation of the strong local current action of Cuyahoga time, and the introduction over the sea floor of gentle bottom currents and widespread wave action which slowly dispersed the upper part of the high-standing masses of Cuyahoga or Black Hand conglomerate. (Hyde, 1927, p. 52)

Merrill (1950, p. 89) and Hall (1951, p. 44) reached similar conclusions in Hocking County, and Root (Root and others, 1961, p. 170) suggested a similar origin for the Berne in Knox County. In contrast, Holden regarded the Berne as "a basal conglomerate representing coarse materials from rejuvenated erosion of adjacent lands" (Holden, 1942, p. 66).

Hyde's hypothesis is difficult to refute, and it may well be entirely correct. The evidence that the crest of the Hocking Valley tongue stood above sea level at the end of Cuyahoga deposition is not conclusive. The writer feels, however, that the channel-like irregularities of the crest of the Hocking Valley tongue are more readily explained by subaerial erosion than by marine planation.

BYER, ALLENSVILLE, AND VINTON DEPOSITION

The Byer and Vinton members were deposited under rather uniform shallow marine conditions. They are strikingly similar in lithologic character, and their separation would be impossible without the intervening, thin, coarse-grained sandstones of the Allensville. Probably no major change in regimen other than slight shoaling, as proposed by Hyde (1915, p. 775), is indicated by the occurrence of the Allensville member.

In the final stages of Berne deposition, subsidence of the basin and probably also compaction of the basin sediments carried the delta surface downward into a zone of decreased turbulence and terminated Berne deposition. Concurrently the silts and fine sands of the Byer member were deposited on top of the Berne and overlapped the Berne to lie directly on the Black Hand at the crest of the Hocking Valley tongue.

Except for the brief episode of slightly increased turbulence which resulted in the deposition of the Allensville, gentle currents and wave action continued to spread the fine-grained clastic sediments of the Logan across the subsiding basin floor. The depositional floor did not subside uniformly. Gentle compaction over the buried interdistributary troughs of the Black Hand delta caused more rapid subsidence in these areas throughout much if not all of Logan time. The differential compaction resulted in the accumulation of a greater thickness of the Byer in eastern Fairfield County and warping of the Allensville member. The Vinton probably also accumulated to a greater thickness in eastern Fairfield County, but subsequent erosion has removed all evidence of this.

The writer found no data in Fairfield County which indicate the source of the Byer, Allensville, and Vinton members. Some generalizations, however, may be made on the basis of data available elsewhere in the State. According to Hyde (1915, p. 773-775) the members of the Logan formation pass westward into shales in southern Ohio. The Allensville member also becomes finer grained to the north along the outcrop in Hocking and Fairfield Counties (1915, p. 776). A southeastern source for the upper three members of the Logan may be inferred. Root (Root and others, 1961) determined that the source of the Allensville member in Knox County lay to the south-southeast.

POST-LOGAN TIME

With the exception of a brief marine invasion, Fairfield County persisted as a land area throughout the remainder of the Mississippian period. This lengthy erosional episode was interrupted by the deposition of the marine Maxville limestone on the eroded surface of the Vinton member. Subsequent emergence resulted in nearly complete removal of the Maxville so that the basal Pennsylvanian sediments were deposited on a land surface carved in the Vinton member.

POST-MISSISSIPPIAN TIME

POTTSVILLE DEPOSITION

In early Pennsylvanian time, sandstones and shales of probable fluviatile origin were deposited on the eroded surface of the Vinton member. Occasional beds of coal in the stratigraphic column indicate that the local coal swamps existed from time to time. Evidence of only one marine transgression has been found in Fairfield County. Fragments of fusuline-bearing limestone occur on one of the higher hills in section 24, Rush Creek Township.

LATER PENNSYLVANIAN AND EARLY PERMIAN TIMES

No consolidated rocks of younger age than Pottsville are known in Fairfield County. However, according to Stout, Ver Steeg, and Lamb (1943, table I), an aggregate thickness of nearly 1500 feet of later Pennsylvanian and early Permian strata overlies the Pottsville in southeastern Ohio. These strata contain alternating deposits of coal, clay, shale, sandstone, and limestone formed in a subsiding basin under the control of a widely fluctuating strandline. It is not unlikely that most or all of these strata once buried Fairfield County and have been removed by subsequent erosion.

LATER PERMIAN, MESOZOIC, AND CENOZOIC TIMES

No strata of younger age than early Permian are present in Ohio or adjacent areas, and with the exception of the coastal plain areas, no post-Paleozoic marine strata are known in eastern North America. It is probable that erosion has been the dominant geologic process since early Permian time in Fairfield County.

The most important single event in the preglacial history of Fairfield County after early Permian time was the regional uplift which brought the Paleozoic strata to their present position. As a consequence of uplift the earlier aggradational regimen was replaced by a degradational one. As the late Paleozoic strata were stripped from the area, a drainage system or drainage systems evolved. The drainage evolution culminated in the Teays system, which transported the surface waters of Fairfield County to the northwest and eventually into the Mississippi drainage. The Teays drainage in western Ohio is believed to have ended with damming by the advance of a pre-Illinoian ice sheet (Durrell, in Geol. Soc. America, 1961, p. 55), but no drainage change is known to have affected Fairfield County at this time. The resulting Deep Stage drainage was strikingly different from the Teays drainage in pattern and direction of flow elsewhere in Ohio, but in Fairfield County there was no observable change; the Deep Stage streams occupied the same valleys and flowed in the same directions as the Teays-cycle streams.

With the advance of the Illinoian glacier, the first glacier known to have invaded Fairfield County, much of the earlier drainage system was buried under glacial deposits, and south of the Illinoian border the old valleys were filled with Illinoian outwash. The Illinoian ice came from the northwest, representing an expansion to the southeast by the Scioto glacial lobe. Ice must have covered most of the county, as indicated by the presence of deposits of highly weathered and eroded Illinoian till as far south as the hills above Clark Crossing along the Hocking Valley and below, east of, Revenge on Clear Creek. During this time, melt water from the Illinoian glacier carried outwash (sand and gravel) southward down the Hocking Valley and eastward down the valley between Lancaster and Bremen. Because two levels of Illinoian outwash are recognized in the Hocking Valley, two separate advances of the Illinoian ice are postulated. The retreat of the Illinoian glacier from Fairfield County signaled the beginning of an ice-free interval during which stream channels were cut into the Illinoian outwash and soil was formed.

The next glacier to invade Fairfield County was the "early" Wisconsin glacier. Determination of the southernmost extent of this glacier depends on the interpretation of the deeper soils on the Rushville moraine and associated drift. If these soils are considered to be truly older, that is of "early" Wisconsin age, then the maximum extent of the Rushville moraine also represents the maximum extent of this "early" Wisconsin advance. On the other hand, if the Rushville moraine is considered to be entirely "late" Wisconsin in age, then the boundary of the "early" Wisconsin ice must be buried under the "late" Wisconsin deposits somewhere north of Lancaster. Regardless of the exact location of the terminus of the "early" Wisconsin glacier, outwash from the melting ice poured into the Hocking Valley, filling the valley with sand and gravel to the level of the Lancaster terrace, the higher of two Wisconsin terraces in the valley. As the glacier retreated to the northwest, some deposits of sand and gravel (outwash) were accumulated in areas other than the Hocking Valley, and it is in these areas that buried soils, covered by the till deposited by the subsequent glacier, have been observed. The soil development in these gravels, and also in all the exposed deposits, took place between the retreat of the first Wisconsin glacier and the advance of the last, an interval of perhaps 20,000-30,000 years. During this time also, streams cut channels into the recently deposited glacial outwash, leaving the uneroded outwash to form the Lancaster (higher Wisconsin) terrace.

The "late" Wisconsin glacier was the last glacier to invade Fairfield County. It advanced from the northwest about 21,000 years ago to the position of either the New Salem or Rushville moraines (depending on the interpretation), covering the older deposits with a deposit of till. In places the soil formed at the surface of the "early" Wisconsin deposits was destroyed; in other places it was preserved, capped by the younger drift.

One of the major stands of the "late" Wisconsin ice front was at the Johnstown moraine, as evidenced by the size of the moraine, the number of glacial features associated with it, and the persistence of the moraine across a number of other counties to the north. While the ice stood at the Johnstown moraine and was depositing material there, melt water washing southward off the moraine deposited a broad gravel plain (kame terrace) against the rocky upland (Chestnut Ridge) in the area of Carroll, and spread outwash southeastward down the valley of the Hocking, forming the Carroll terrace surface. Pits in the surface of the kame terrace and in the adjacent outwash indicate that chunks of ice broken from the glacier were also embedded in the deposit. Local hills of gravel incorporated in the end moraine itself indicate that melt water was washing rock debris into depressions on the waning margin of the glacier. In front of the moraine stood the broad shallow predecessor of Buckeye Lake. It was at this time that fine-grained material, presumably picked up from the outwash along the various rivers in Fairfield County and to the west, was blown eastward over the county to accumulate as local thin loess caps over the till. The processes involved in this deposition of loess lost their effectiveness after the glacier had retreated from this moraine, as indicated by the lack of a loess cap on the drift west of the Johnstown moraine. A long narrow tunnel within the ice extended from Pickerington to near Basil (Baltimore), although not all this distance at the same time, and carried melt water which deposited sand and some gravel derived from the "dirty" ice at the base of the glacier. When the ice melted as it retreated from the Johnstown moraine, the bottom deposit of this stream in the ice was let down onto the ground and left as a winding ridge of sand called an esker. Where the bottom of this channel in the ice locally was higher, little or no sand accumulation was necessary to maintain a level bottom for the ice-enclosed stream. When the ice melted, low spots in the resulting ridge (esker) formed where little or no sand had been deposited in the old channel in the ice, thus making the esker appear discontinuous today.

After building the Johnstown moraine, the ice retreated to the northwest. A minor readvance, as indicated by the change in soils from Miami 60 (and Alexandria) soils to Miami 6A (and Alexandria), brought the ice back to the Canal Winchester moraine. While the ice front stood at this moraine, another tunnel, oriented northwest-southeast and terminating at its lower end in the area of kames west of the moraine, formed within the ice in adjacent Franklin County. This tunnel also filled with sand and some gravel, but again, presumably because of the irregular surface of the ice making the floor of the stream channel in the tunnel, the resulting esker is markedly discontinuous. Where the tunnel came close to the ice margin, the glacier apparently was deeply crevassed and broken; gravel filled these holes, creating the kames located west of the village of Pickerington and the Canal Winchester moraine. A small shallow lake was also present at this time just east of the moraine, near and in the valley of Big Walnut Creek. Starting when the ice front stood at the Canal Winchester moraine, or shortly before, the drainage began flowing southwest into the Scioto River system; all drainage from this part of Fairfield County has gone to the southwest ever since.

Following this stage in the glacial history of Fairfield County, the ice retreated out of the county, never to return. Since this retreat, modern streams have cut channels in the Wisconsin gravel outwash, creating one or more levels of "cut" terrace, and finally have cut to the level of the present flood plains.

Chapter 7

GLACIAL GEOLOGY

By Jane L. Forsyth

INTRODUCTION

Features of glacial origin have been recognized in Fairfield County since 1874, when E. B. Andrews described the glacial drift and outwash terraces of the area (all historical data given here are from Conley, 1956). G. F. Wright (1884) traced the outer Wisconsin boundary through Licking and Perry Counties and T. C. Chamberlin (1883) continued the tracing of this boundary into Fairfield County, naming it the "Wisconsin terminal moraine of the Scioto Glacier" (1883, p. 338). In 1897, W. G. Tight presented his analysis of the drainage changes which had taken place in Rush Creek valley, postulating that a river had once flowed into the Hocking Valley by way of the now-abandoned valley between Bremen and Lancaster. Frank Leverett (1902), in his classic report on the "Glacial Formations and Drainage Features of the Erie and Ohio Basins," included a reconnaissance survey of Fairfield County. Following this, J. E. Hyde (1912) published a short geological history of the county, in which he discussed bedrock geology, glaciation, and glacial drainage changes.

More recently, G. W. White (1939) mapped the Illinoian deposits of a large area which included Fairfield County. Subsequently, C. A. Reutinger (1941) described the "Pleistocene Geology of the Thornville Quadrangle." In 1938 and 1943, Wilbur Stout and others published discussions of the pre-Illinoian drainage systems of the area. R. L. Schuster (1952) mapped the glacial deposits of adjoining Pickaway County in detail, and on the basis of soils differences he recognized two ages of till along the moraine that he called the Marcy (the moraine extending northeast of Circleville). J. P. Kempton (1956; Kempton and Goldthwait, 1959) studied the terraces of the Hocking Valley from Carroll to the Ohio River, and his results in Fairfield County are incorporated in this chapter. A survey of the glacial geology of Fairfield County by J. F. Conley, completed in 1956, brought together and analyzed all the significant data on the glacial features of the county. This work has formed the basis of the present report and has been the source of a great deal of the information presented here. Rather than burden this report with continual references to Conley's work, the author has cited Conley's thesis only in instances of special information, observation, or interpretation.

PRE-ILLINOIAN GLACIAL DEPOSITS

No glacial drift of unquestioned pre-Illinoian age is recognized in Fairfield County, although a glacier of this age is known to have invaded western Ohio (Durrell, in Geol. Soc. America, 1961, p. 55). It is possible that drift of this age may occur at depth, particularly in those areas where the cover of glacial material is especially thick. Though drift is generally thin throughout most of the county, there are several deep valleys which have been filled with thick drift. It is possible that the basal materials of the filling of these buried valleys, which are considered to be a part of the preglacial northwestward-flowing Teays drainage system (see p. 96), may represent drift of pre-Illinoian age.

ILLINOIAN GLACIAL DEPOSITS

The Illinoian glacier was the first glacier to leave deposits of unquestioned glacial origin in Fairfield County. Like the later Wisconsin ice, this early advance represented an eastward expansion of the Scioto ice lobe from the west (Leverett, 1902, p. xiii), so ice movement was toward the east or southeast across the county.

GROUND MORAINE

The area of Illinoian drift (pl. 2 and fig. 41) includes a belt of ground moraine 1 to 6 miles wide across the southeastern part of the county (fig. 36). The area is widest to the east and separates a small area of unglaciated land (fig. 37) in the south from the extensive area of Wisconsin deposits to the north, northwest, and west. No true end moraine or other marginal glacial features mark the terminal position of the Illinoian ice.

The outer border shown on the map represents simply the maximum extent of identifiable Illinoian drift, as determined by the presence of (1) deeply weathered till, (2) glacial erratic stones, and (3) Illinoian soils as shown on the recently published soils map of Fairfield County (Meeker, Petro, and Bone, 1960). It is probable that the margin of the ice actually extended farther to the southwest than can be recognized by these criteria, but since no glacial deposits remain there by which this extent can be determined, the true boundary cannot be mapped.

The Illinoian drift is everywhere quite patchy. It is generally thickest on the lower slopes of valleys, but local thin till and scattered erratic stones on some of the hilltops indicate that they, too, were covered by ice. Boulders are rare on the till surface, but weathered igneous boulders more than a foot in diameter have been observed buried in the soil (Conley, 1956, p. 24).

The Illinoian till, which generally is covered by 1 to 2 feet of silt (probably mostly loess), has soils of the Hanover catena developed in it. Because the till is fairly thin over the bedrock in most areas, the soil profile is almost everywhere incomplete and the entire thickness of till generally is oxidized and leached throughout. Calcareous Illinoian till has been observed (Conley, 1956, p. 24) in only one place in the county (fig. 38), in a road cut a few hundred yards west of the Old Pine Bluff School, 2 miles south of Revenge in Madison Township (SW$\frac{1}{4}$NW$\frac{1}{4}$SE$\frac{1}{4}$ of sec. 22). The top of this stratigraphic section, because it is on the edge of a slope, is somewhat eroded, so that the depth to carbonates here, 89 inches, is a minimum value for the depth of leaching in Illinoian till.

OUTWASH TERRACES

A great volume of sand and gravel was washed out from the Illinoian glacier by melt water and was deposited in the Hocking Valley and in the valley between

Figure 36. - Typical Illinoian glaciated country (ground moraine) in Fairfield County. View is toward the northeast, 1 mile south of Delmount and 4 miles northeast of Amanda (NE$\frac{1}{4}$, sec. 29, Hocking Twp.).

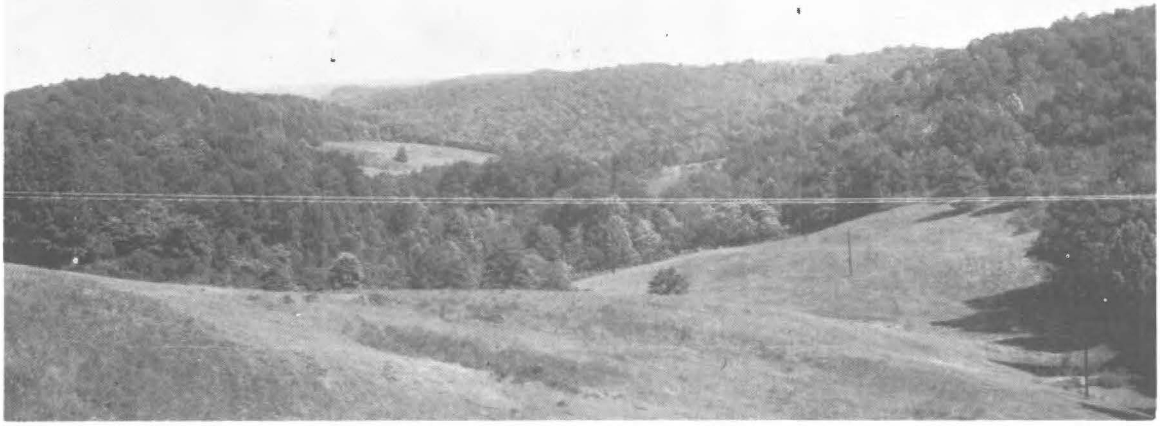


Figure 37. - Typical unglaciated country in Fairfield County. View is toward the east, 1 mile south of the Boys' Industrial School (center of sec. 1, Madison Twp.).

Lancaster and Bremen. After the retreat of the Illinoian glacier, streams cut into these outwash deposits, eroding most of them away. All that remains of the outwash today are local terrace remnants along the sides of the valleys. In places, some of these remnants are fairly extensive; elsewhere all that is left of these terraces is a few scattered pebbles. These outwash terraces and the Wisconsin-age outwash terraces in the county are described as valley-train deposits in the discussion of groundwater resources, on pages 160 and 162.

Figure 38. - View of till at the only locality in Fairfield County where calcareous Illinoian till has been reported, 3 miles south-southeast of Clearport (SE$\frac{1}{4}$, sec. 22, Madison Twp.). Hammer points to the depth of leaching (note rounding of top of bank, which suggests that due to erosion the depth of leaching is less than average). (Photograph from Conley, 1956)

HOCKING VALLEY

Two levels of Illinoian outwash are present in the Hocking Valley (Conley, 1956, p. 54; Kempton and Goldthwait, 1959, p. 138). The only remnant of the higher Illinoian terrace in Fairfield County occurs north of Tarkiln School, Berne Township (NE$\frac{1}{4}$ of sec. 20), at an elevation of 935 feet. However, other remnants of this terrace have been mapped farther down the valley, beyond the county line (Kempton, 1956; Kempton and Goldthwait, 1959).

The lower and more extensive of the two Illinoian terraces in the Hocking Valley (fig. 39) represents a filling of the valley to a level of from 60 to 90 feet above the present river level. The most northern occurrence of this terrace is considered (Conley, 1956, p. 54) to be within the hill in the center of Lancaster. Though it is now covered by Wisconsin till, this hill is composed mostly of gravel which is believed to be a remnant of the lower Illinoian terrace. The northernmost occurrence of this terrace where not covered by other deposits is just south of the Lancaster city limits, at an elevation of 930 feet. Other remnants of this same terrace are present on both sides of the Hocking Valley for several miles to the south, occurring as far south as a point just northwest of Clark Crossing. The lowest of these remnants is at an elevation of 926 feet. Abundant remnants of this

Figure 39. - Illinoian terrace with pit exposing outwash gravel. View is toward the west, 3 miles south of Lancaster, on U. S. Route 33 (NE$\frac{1}{4}$, sec. 20, Berne Twp.). The skyline marks the top of the terrace.

same terrace are also reported by Kempton farther down the Hocking Valley, beyond the Fairfield County line (Kempton, 1956; Kempton and Goldthwait, 1959).

Throughout the Hocking Valley, these terraces are composed of generally well sorted sand and gravel, which is poorly stratified in some places and which in most places is capped by as much as 5 feet of silt. The silt shows lamination in places (Conley, 1956, p. 56). Therefore, though much of it is considered to be loess, some of the silt (including some of the loess?) must have been waterlain. Soils developed in the terrace gravels include members of the Negley, Parke, and Pike catenas, the differences between these catenas being in the thickness of the silt cap. Carbonates in these terrace soils have been leached to depths of from 10 to 15 feet. Layers of calcareous gravel below these depths in many places are locally cemented with secondary calcite, creating a natural concrete. This natural concrete, together with the thickness of the overburden of silt and soil, makes the gravel difficult and expensive to excavate, thus lowering its commercial value.

VALLEY BETWEEN LANCASTER AND BREMEN

Remnants of Illinoian outwash are present in the valley between Lancaster and Bremen, that is, the area from 3 miles east of Lancaster eastward to the county line. The outwash forms a set of matching terraces which slope to the east, decreasing in elevation from 913 feet at North Berne to 872 feet east of Bremen. The terraces are composed of sand and gravel which become progressively finer in size eastward, until only fine sand occurs northwest of Bremen (Conley, 1956, p. 57). This decrease in particle size, together with the gentle eastward slope of the terrace surface, indicates that the melt water which deposited these terraces flowed eastward from its origin in the melting glacier west of Lancaster. From the east end of the valley, 3 miles southeast of Bremen, this stream turned southward and then bent westward through the hills, joining the Hocking Valley again near Clark Crossing.

OTHER AREAS OF ILLINOIAN OUTWASH

Small Illinoian terraces also occur (Conley, 1956, p. 58) in the valleys of Clear Creek, southeast of Clearport; Black Run, southwest of the Boys' Industrial School; upper Blue Valley, east of the Boys' Industrial School; and the tributaries of Rush Creek, northeast of Sugargrove. As these streams are all tributaries of the Hocking River, the outwash probably was deposited contemporaneously with that in the lower Illinoian terrace of the Hocking Valley. In places where the tributary valleys did not drain from the glacial margin itself, no glacial gravels occur; terraces present in these valleys are composed of silt or fine sand and represent deposition in the slack-water areas created by the dam of outwash gravels in the main valley.

WISCONSIN GLACIAL DEPOSITS

The Wisconsin glacier, which was the last of the two or three glaciers to invade Fairfield County, left abundant deposits throughout the central, western, and northern parts of the county, but in no place did it extend far enough to cover completely the older Illinoian drift. Because of the recency of their formation, the Wisconsin deposits have been much less affected by erosion than have the deposits of the preceding Illinoian glacier. Broad areas of ground moraine occur, which appear low and flat to the north and far west and which are quite hilly where the ground moraine represents simply a thin veneer of glacial till over bedrock hills. These areas of ground moraine are separated by irregular belts of end moraine characterized by much thicker, more hummocky deposits of drift. Kames occur locally, in association with all the end moraines. Two levels of constructional outwash terrace are present, mainly in the Hocking Valley, as well as several large areas of lacustrine deposits.

END MORAINES AND ASSOCIATED SOILS

A series of end moraines extend irregularly from northeast to southwest across Fairfield County and represent a sequence of recessional positions of the Wisconsin ice margin. From oldest to youngest (southeast to northwest), these ice-edge positions are marked by the Rushville moraine, the New Salem and Lithopolis moraines, the Johnstown and Cedar Hill moraines, and the Canal Winchester moraine (pl. 2 and fig. 41). Correlation of individual moraines from northeast to southwest across the county has been established tentatively, but is uncertain in some places because of the irregularity and discontinuity of the moraines. Wherever a major preglacial valley is present, such as that of the Teays-age Groveport River in northern Fairfield County, end moraines bend far east or south up these old valleys. Where bedrock uplands are present, the moraines bend far back to the northwest and "wrap around" the foot of these uplands or, in places, are entirely absent. The highest and most extensive of these bedrock uplands is Chestnut Ridge, in northwestern Bloom Township, which causes major westward projections in the trends of all the end moraines.

Because soils play such a significant role in the interpretation of the glacial history of Fairfield County, two sections discussing soils are included in this chapter;

the older Wisconsin soils are discussed on pages 126-128 (after the description of the New Salem and Lithopolis moraines) and the younger Wisconsin soils are described on pages 132-133 (following the section dealing with the Canal Winchester moraine).

RUSHVILLE MORAINE

The Rushville moraine is the terminal moraine of the Wisconsin glacier and forms a broad belt, about 3 miles wide, along the Wisconsin glacial boundary in central and northeastern Fairfield County (pl. 2 and fig. 41). It extends from just east of Buckeye Lake southward to Rushville and, from there, southwest to a point just north of Lancaster. South of Lancaster, no end moraine is mapped because the till is thin and bedrock projects through the drift as rock knobs in many places. Consequently, it is not known where the Rushville ice edge stood in that part of the county. Soils might provide an answer to this problem, except that the effects of sandstone contamination on soil morphology here are not well enough understood to be discounted (see p. 126).

In places, the Rushville moraine occurs immediately adjacent to a younger moraine, the New Salem. The distinction between these two moraines, although not everywhere clear, is based on relative position, orientation of moraine trends, and the possibility (Conley, 1956, p. 26 and 31-32) that different soils may be present (see p. 126 in this chapter).

Soils developed in the till of the Rushville moraine belong to the Alexandria catena. They are in most places about 45 to 50 inches deep, though the depth of leaching is greater, varying from 40 to 70 inches. A silt cap of 12 to 18 inches, interpreted to be of aeolian origin, is present in places (Conley, 1956, p. 31). The Rushville moraine has a relief of from 50 to 80 feet and is characteristically hummocky. The crest of the moraine is highest and most persistent southwest and north of Rushville (pl. 2).

NEW SALEM AND LITHOPOLIS MORAINES

The New Salem moraine, the second in the sequence of moraines in northern and central Fairfield County, lies in Walnut, Pleasant, and Greenfield Townships (pl. 2 and fig. 41). It is named for the town of New Salem in Walnut Township. In places this moraine lies directly against the Rushville moraine; in other areas the two are separated by areas of ground moraine that may be as wide as 3 miles. It is distinquished from the Rushville moraine by its relative position, by differences in moraine orientation, and possibly by what is believed by Conley (1956) to be a somewhat younger soil (see p. 126).

The New Salem moraine can be traced easily from the town of New Salem in eastern Walnut Township southwestward in a broad arc around Pleasantville to a point 1 mile west of Dumontville (pl. 2 and fig. 41). From here it bends back to the southeast, forming a narrow discontinuous belt along the western foot of the bedrock hills north of Lancaster. It is recognized again in the lower hills south of Lancaster, from where it can be traced westward along Hunters Run, marked by irregular outlines due to protruding bedrock hills, and then northwestward along the eastern side of Chestnut Ridge. The segments between Dumontville and Chestnut Ridge outline the position of a small sub-lobe of this ice which pushed southeast down the valley of the Hocking River. From the east side of Chestnut Ridge, the position of the New

Salem moraine ice margin can be traced northwestward through small areas of end moraine and kames in southwestern Greenfield and eastern and northeastern Bloom Townships into the eastern part of the large morainic area on the upland directly west of Chestnut Ridge, near Lithopolis. The ice which deposited the New Salem moraine apparently rose up onto the large bedrock highland, but did not cover the higher, more southeastern parts of it. In places, the moraine lies against the sides of the higher bedrock hills, probably outlining the position of the ice itself against these hills. In these places, the end moraine is recognized by its hummocky surface and linear outline (fig. 40).

The large area of moraine on the Chestnut Ridge upland is called the Lithopolis moraine in this report because of its proximity to the town of that name. However, it should be made clear that the extent of this moraine, the details of its outline, and its orientation differ considerably from what was originally called the Lithopolis moraine by Stout, Ver Steeg, and Lamb (1943, map 1 opposite p. 21). Because of its location on top of a bedrock upland, many questions as to the correlation of this moraine have been raised in the past. It is on the basis of the position and arrangement of the various moraine segments among the bedrock knobs on the eastern side of Chestnut Ridge that the probable correlation of the Lithopolis and New Salem moraines is inferred.

Figure 40. - Wisconsin end moraine in an area of bedrock hills. View is to the southeast, 2 miles northwest of Delmount and 6 miles west of Lancaster (NW$\frac{1}{4}$, sec. 18, Hocking Twp.). Highest hills are ground moraine (bedrock capped by thin till); hummocky topography lying along lower half of farther slope is interpreted as thicker till in the form of end moraine. Arrows indicate position of line separating end moraine and ground moraine.

From the Lithopolis area, this moraine may be traced southward through Royalton to the area northeast of Amanda. Here the position of the ice edge lies only a few miles south of its position west of Lancaster, along Hunters Run, described previously. In the region between Amanda and Hunters Run, end moraine also is recognized among the bedrock knobs (sections 7, 17, 18, 19, and 20 of Hocking Township) (pl. 2 and fig. 41). Apparently, at the time the New Salem-Lithopolis moraine was formed, ice from both the sub-lobe to the northeast and the sub-lobe to the southwest advanced up the two opposing slopes to meet at the top of this bedrock

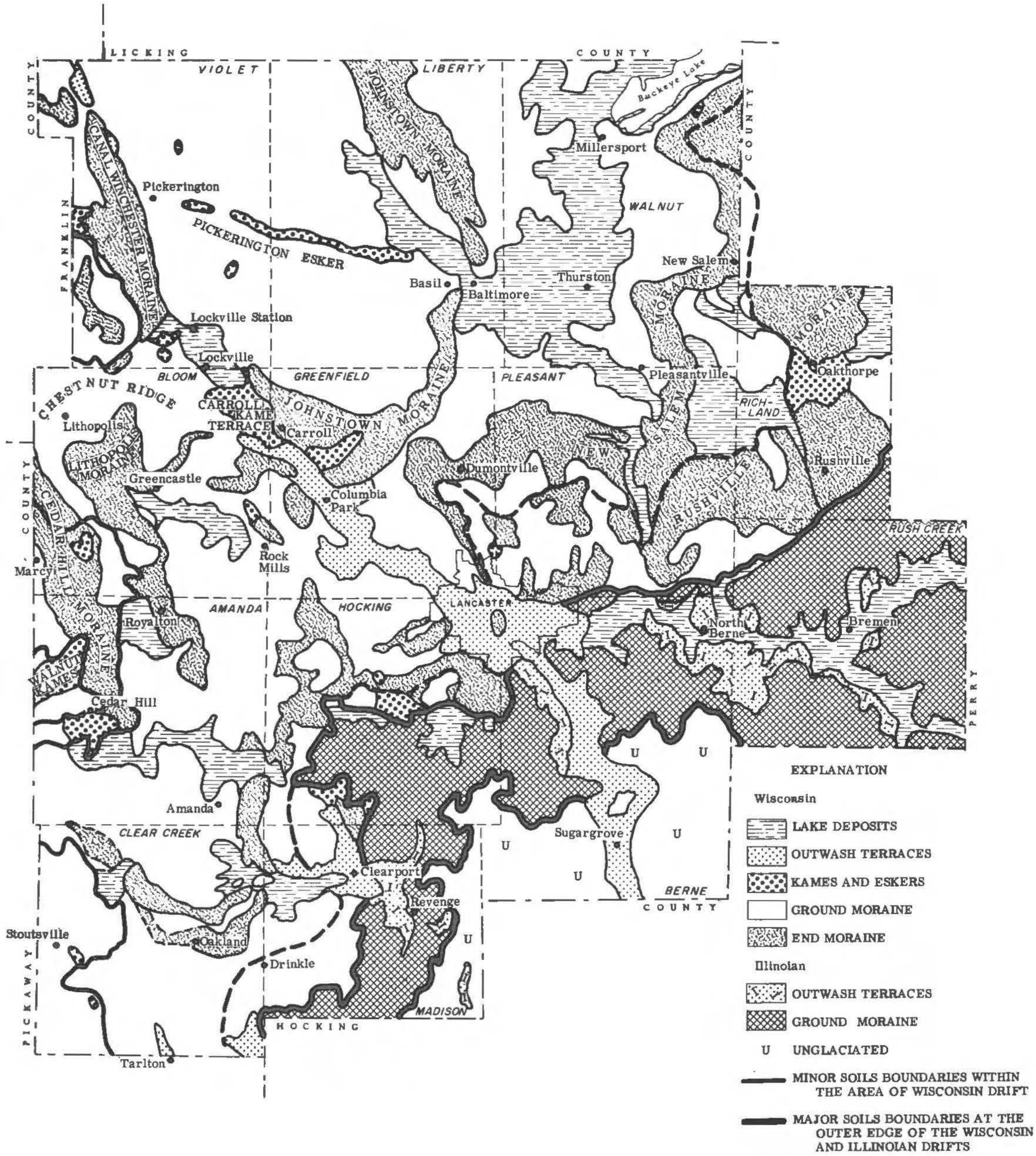


Figure 41. - Map showing the generalized distribution of the glacial deposits in Fairfield County. These deposits are shown in more detail on plate 2.

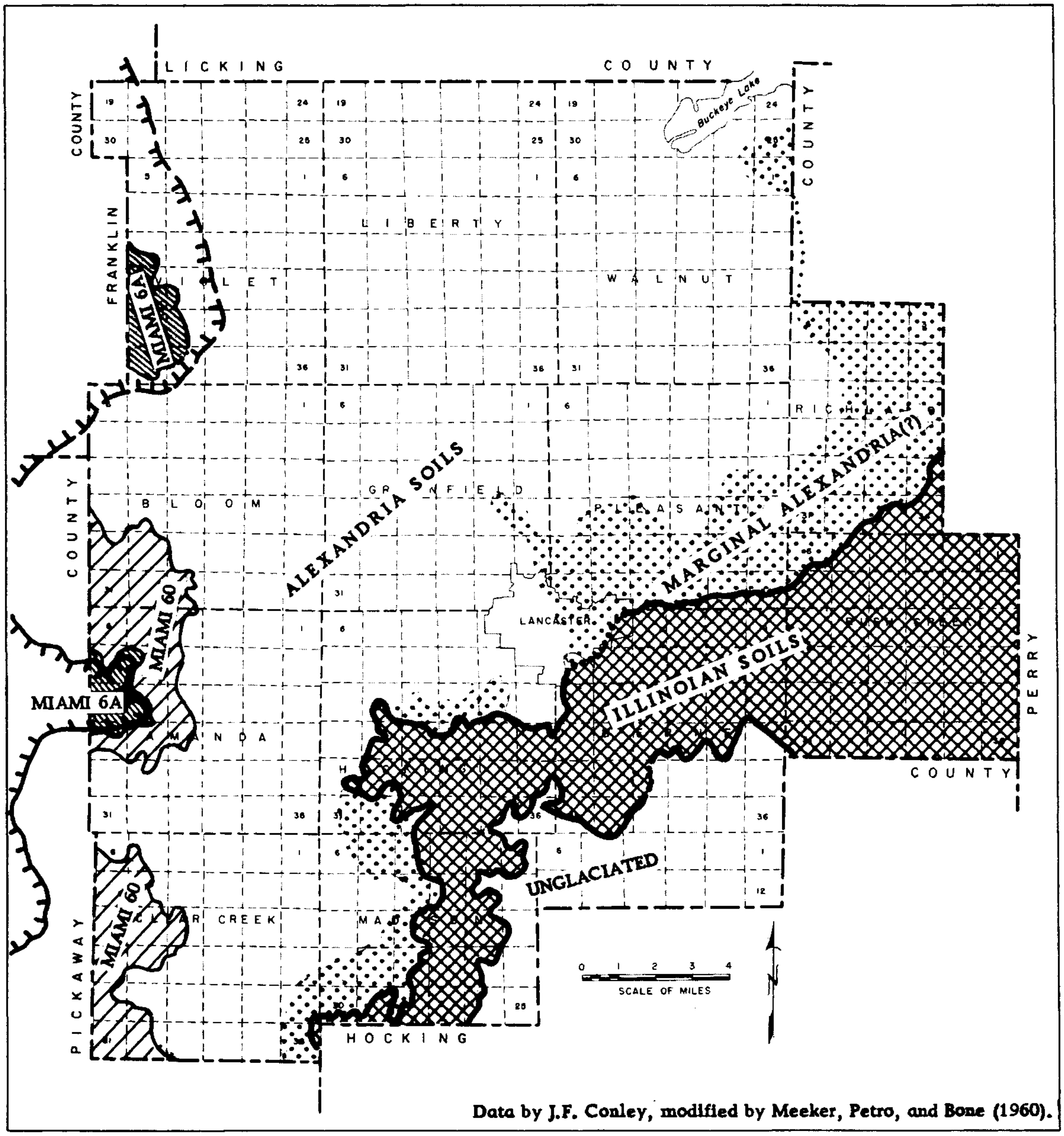


Figure 42. - Map showing the generalized distribution of the major upland soils in Fairfield County. Line with ticks represents probable outer (eastern) boundary of younger drift, characterized by Miami 6A soils in most places.

upland. Thus, this upland, which had been completely covered by the earlier advance of the Wisconsin glacier, this time protruded above the surface of the ice as a series of nunataks.

OLDER WISCONSIN SOILS

Upland soils developed in the tills of the New Salem and Rushville moraines are all mapped in the Alexandria catena by soils scientists (Meeker, Petro, and Bone, 1960). However, Conley (1956, p. 31-32) identified a difference between the soils found on these two end moraines. Soils on the outer, Rushville moraine appeared to him to be somewhat more weathered, a little deeper, and in places to be capped by 12 to 18 inches of silt. He found the solum (clay profile) of these soils to be generally 45-55 inches deep and the depth of leaching to vary from 55 to 70 inches (table 5). Throughout the area where he recognized this deeper soil (shown as "marginal Alexandria" in fig. 42), the land surface appeared to him to be characterized by somewhat better integrated drainage systems and by fewer closed depressions. In contrast, he recognized a somewhat shallower soil on the New Salem moraine, where he measured depths of leaching of from 35 to 45 inches. He felt that this soil, which seemed to lack a silt cap in most areas, appeared less weathered and that the surface on this drift seemed to be characterized by more closed depressions and by slightly less well integrated drainage. As a result of his observations, he concluded that the two drifts, though both Wisconsin, were of different ages. The validity of this conclusion reached by Conley (1956) is questioned by the author (Forsyth), because of the fact that local bedrock can also influence the nature of till, and therefore the nature of the soil developed from it, as will be shown below.

As the glacier advanced from the west, its rock load was rich in limestone, the bedrock of the west. When the glacier entered Fairfield County, however, it moved over so many outcrops of local sandstone that significant amounts of sand were added to its rock load, changing the composition of this load and also, therefore, of the till deposited by the glacier. As the percentage of added sand increased, the percentage of residual lime decreased. The intensity of this change in composition varied, depending on the number of sandstone outcrops passed over by the glacier and the availability of the sand for removal from these outcrops. A high percentage of sand in the glacier's rock load, and therefore in the resulting till, could only occur where the glacier had passed over a particularly large number of sand sources. A higher percentage of sand in a soil provides a more acid condition and therefore allows the development of soil characteristics which might be described as giving a more weathered appearance. A low percentage of lime allows the amount of lime that is present to be leached faster, thus creating deeper depths of leaching than would be expected in soils containing more lime. In addition, it has been generally observed that when there is less lime present in the parent till there is generally less development of clay in the B horizon (measured by comparing the percentage of clay in the B horizon with that in the C horizon). Thus, a soil developed in a till with a significantly greater sand content would tend to have a deeper depth of leaching, a weaker clay profile, and often an appearance of greater weathering. Thus it can be seen that just by the addition of some sandy contaminant in the till, an apparent difference in soils can be developed where no difference in age exists in the till; a single till may simply contain local areas of deeper soil, created wherever the composition of the till was sufficiently modified by additions from the local sandstone bedrock. In Fairfield County, such contamination would be especially likely near the Wisconsin glacial boundary, where such bedrock hills are more common.

That at least part of the observed difference is created by the effect of the bedrock is unquestioned. Does, however, this contamination by the local sandstone

Table 5. - CHARACTERISTICS OF WISCONSIN UPLAND TILL SOILS

	Soil catena			
	Miami 6A[1]	Miami 60[1]	Alexandria[1]	
Associated moraine	Canal Winchester	Cedar Hill	Johnstown[2] New Salem	Rushville[2]
Silt cap	Absent	Absent	Absent except locally	12-18
Depth of leaching, in inches	20-27	24-37	28-60 (35-45)[3]	40-70 (55-70)[3]
Clay content of subsoil (B), in percent[4]	40-50	33-45	28-40	
Clay content of parent material (C), in percent[4]	15-27	15-27	15-27	
Ratio of clay content of B to clay content of C[4]	1.7-3.0	1.4-2.5	1.2-2.0	
Lime content of parent material (C), in percent[4]	28-42	32-47	10-20	

1. No age difference is implied by the separation of the Miami 60 and Alexandria soils; the Alexandria soils are merely the facies of these soils which has a lower lime content, being more affected by the local sandstone bedrock than the Miami 60 soil. The Miami 6A soil is almost certainly a younger soil, developed in a till which has a higher lime content.

2. The Alexandria soils of the Rushville moraine (that occurring outside the dashed line on plate 2 and in figure 42, nearest the Wisconsin boundary) may or may not represent distinctly different soils (p. 126).

3. Depth of leaching reported by Conley (1956, p. 32).

4. Data provided by Dr. George Schafer, Soil Scientist with the U. S. Soil Conservation Service, and Dr. Nicholas Holowaychuk, Professor in the Department of Agronomy, The Ohio State University.

actually create the entire difference observed by Conley between the soils on the Rushville and New Salem moraines, or is this soils difference partly created by a difference in the age of the two tills? The critical point is whether the areas characterized by the two soils are separated by a distinct line, or whether they seem to intergrade. On the basis of his field observations, Conley is convinced that such a line does exist (his line is shown on both pl. 2 and fig. 41 as a dashed line generally separating the Rushville and New Salem moraines) and that the soils on the two sides of this line definitely represent two separate drifts of somewhat different age. If Conley's interpretation is correct, the two ages of Wisconsin drift could provide a possible basis of correlation with other areas; the older of these soils might correlate (see fig. 43) with the deeper Russell soils of Highland County (Forsyth, 1957a and 1957b) and also, possibly, with the Knox Lake soil in Knox County (Root, Rodriquez, and Forsyth, 1961, p. 123). However, the present author (Forsyth) has been unable to recognize any distinct line of demarcation between the deeper

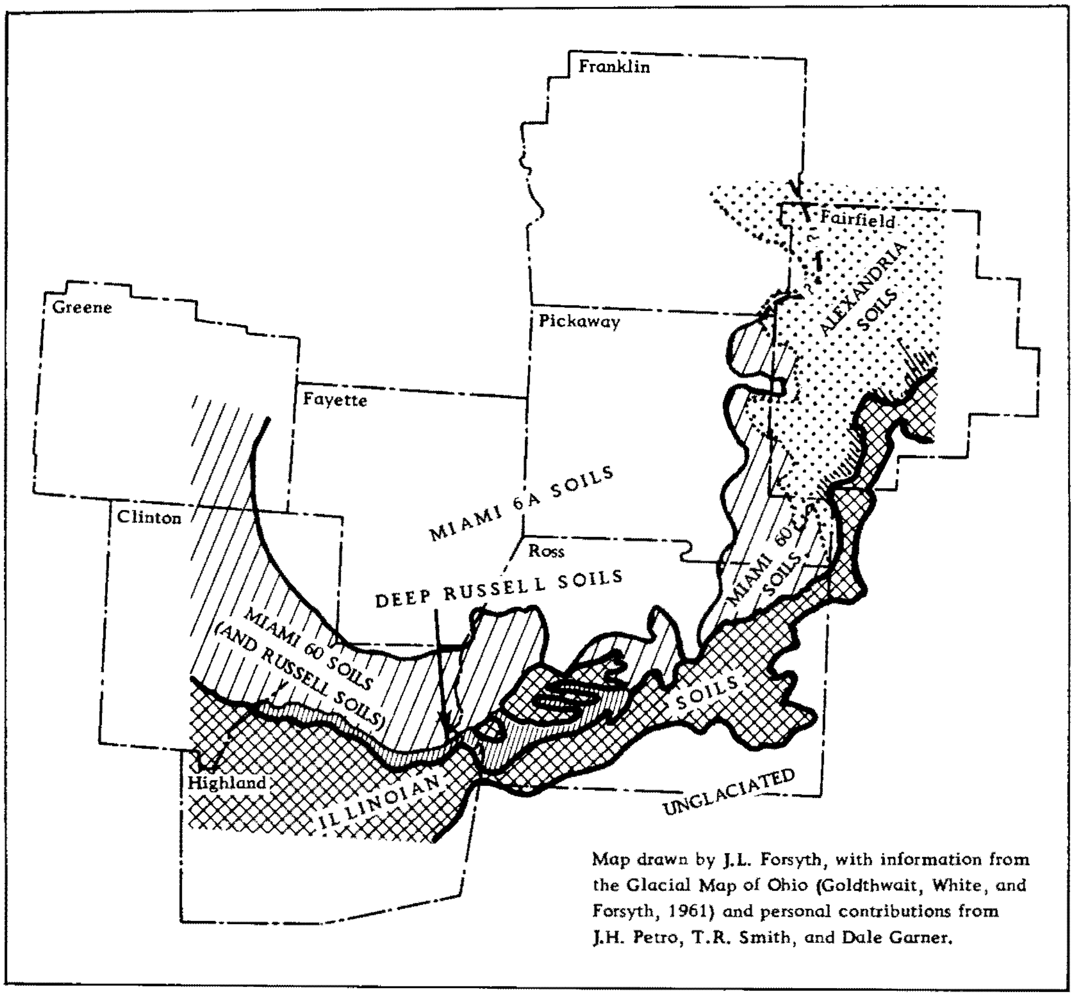


Figure 43. - Map showing the generalized distribution of the major upland soils developed in Wisconsin till in central Ohio. The line between Alexandria and Miami soils is shown dotted because it does not mark a till boundary, but represents only a change in composition of the tills. In the area of Miami 60 soil to the west, where 18+ inches of silt cap is present, Russell soils are mapped. The narrow belt with the fine parallel-line pattern represents a distinct belt of unusually deep Russell soils (equivalent to marginal Alexandria of Fairfield County?).

and shallower soils. Since modification by sandstone contamination is known to have taken place and can adequately explain all the observed differences in soil characteristics, this author prefers to take the simpler interpretation at this time, that of a single age for all the drift associated with these two soils.

JOHNSTOWN MORAINE

The Johnstown moraine, which forms an arc convex to the southeast in the northern part of Fairfield County (pl. 2 and fig. 41), was first recognized, though not named, by Leverett (1902, pl. xiii). It has been commonly referred to since the time of his work as the Johnstown moraine, for the town of that name in Licking County, to the north.

The arc formed by the moraine begins at the center of the Fairfield-Licking County line and extends southward to Baltimore, where there is a break in the moraine, and then southwestward and westward to Carroll. Kames lie along the outer crest of this moraine 2 miles southeast of Carroll. West of Carroll is a kame terrace which seems to be related to the same ice edge and which represents the upstream end of the Carroll terrace, the lower of the two Wisconsin constructional terraces present along the Hocking River valley (see also Kempton, 1956, and Kempton and Goldthwait, 1959). This relationship indicates that this lower terrace was built when the ice edge stood at the Johnstown moraine, thus presenting a basis for correlating this terrace with other terraces along other Ohio rivers which originate at the same (Johnstown or equivalent) moraine (see discussion in Root, Rodriquez, and Forsyth, 1961, p. 132 and 135). The actual moraine can be traced westward only as far as a point just northwest of Carroll, but the position of the Johnstown ice can be traced on to the northwest, southwest, and south, curving around the foot of Chestnut Ridge. Apparently the Johnstown ice was unable to advance even part way up this high Mississippian bedrock promontory.

The correlative of the Johnstown moraine to the south and southwest is not known for certain, but on the basis of the position of the ice edge interpreted above, it would seem to be the Cedar Hill moraine, which is mapped in Bloom and Amanda Townships. This correlation seems strange when viewed on a map lacking surface contours (fig. 41), but it makes sense when the high bedrock upland of Chestnut Ridge is seen (pl. 2), around which the ice edge had to bend.

The Johnstown moraine is quite hummocky in most areas and rises to a maximum of about 40 feet above the general level of the land. Because this moraine in places lies on areas held high by resistant underlying bedrock, as for example in northern Liberty and northeastern Greenfield Townships, the moraine gives an appearance of exaggerated height, due to the bold preglacial topography. In these areas, it is the presence of a persistent belt of more hummocky land cutting across broad high areas of nonhummocky land (ground moraine) that identifies the end moraine. This differentiation of a belt of end moraine from land that is also high, but only because the underlying bedrock surface is high, is often very difficult, but the problem is common in areas like this where the glacier overrode a margin of the Appalachian Plateau.

Soils on the Johnstown moraine lack a silt cap and are characterized by a dark brown B horizon. The depth of leaching varies from 28 to 60 inches, but is generally 35 to 45 inches (Conley, 1956, p. 32). In most of the available exposures, the till is oxidized throughout; only rarely is a cut deep enough (12 to 14 feet) for the unoxidized dark gray till to be seen.

CEDAR HILL MORAINE

The Cedar Hill moraine forms a low northwest-southeast-oriented ridge in western Bloom and Amanda Townships, just east of the town of Marcy (pl. 2 and fig. 41). In the past, a moraine called the Marcy, which had a somewhat different outline and markedly different orientation, was mapped in this same area by Stout (Stout, Ver Steeg, and Lamb, 1943, map 1, opposite p. 21). This moraine extended from near the town of Marcy southwest to near Circleville, in Pickaway County. Subsequently, on the "Glacial Map of Ohio" (Goldthwait, White, and Forsyth, 1961), the name "Marcy" was applied to an abbreviated portion of Stout's Marcy moraine, that segment lying near Circleville. To avoid confusion in the present report, the northwest-southeast-trending moraine in western Bloom and Amanda Townships of Fairfield County, even though located near the town of Marcy, will be referred to as the Cedar Hill moraine, for the crossroads community of that name which lies adjacent to the moraine in western Amanda Township. Kames make up part of the moraine crest east of Marcy and immediately south of Cedar Hill, where the moraine appears to end. From the kame south of Cedar Hill, the ice edge apparently bent sharply to the west, along the northern edge of a bedrock highland, into Pickaway County, where its position is unrecorded by any mappable marginal deposit. To the north, the Cedar Hill moraine extends diagonally out of the county into the northwest corner of Pickaway County and the southeast corner of Franklin County. Morainic characteristics are lost about a mile or so east of the Fairfield County line, but the position of the ice edge marked by this moraine doubtless follows the outer slopes of the adjacent highland, Chestnut Ridge, around to the north and east, so that farther east it appears to meet the Johnstown moraine, with which it is here correlated.

Like the Johnstown moraine, the Cedar Hill moraine is quite hummocky. In places it forms a fairly obvious ridge above the general land level; in other places it is such a low feature that it is difficult to identify. The drift of this moraine is probably nowhere particularly thick; even where the moraine is highest in elevation, in western Bloom Township, the elevation appears to be due more to the height of the underlying bedrock surface than to the thickness of the till composing the moraine.

Soils on this moraine, which are free of any silt cap, are characterized by a a dark brown B horizon and an average depth of leaching of from 24 to 37 inches (table 5). Cuts which expose the unoxidized, dark gray till are rare.

CANAL WINCHESTER MORAINE

The Canal Winchester moraine is present only in the northwestern corner of Fairfield County, along the west boundary of Violet Township (pl. 2 and fig. 41). It forms a belt of rounded hummocks 5 to 30 feet high (fig. 44), which extends from the northwestern corner of the county, where the moraine lies on the lower, western slopes of a bedrock upland (actually the outer margin of the Appalachian Plateau), to a point 2 miles southeast of Canal Winchester. The moraine lies mainly west of the Pickerington-Waterloo road, except in the eastern part of section 21, about 2 miles south of Pickerington, where the road turns toward the southwest and crosses the crest of the moraine. A main highway, U. S. Route 33, crosses the crest of this moraine a mile and a half farther south, 2 miles east of Canal Winchester, in the southeast corner of section 28.

The moraine is named for the town of Canal Winchester, in Franklin County, which lies about 2 miles west of the moraine in southern Violet Township. This is the same moraine called the Pickerington moraine by Goldthwait (1958b, p. 18), but because this name had already been used by Leverett (1902, p. 428) for the esker in east-central Violet Township, the name "Canal Winchester" is recommended here as the name for the moraine (this name was also used by Conley, 1956, p. 40).

At the northwestern corner of the county, the moraine is present on the south bank of Blacklick Creek in section 29, on the west side of Blacklick Creek valley in section 19, and across the southern edge of the bedrock-supported ridge west of the creek in sections 19 and 30 (on which is located part of Blacklick Park of the Columbus Metropolitan Park Board). North of here, in Franklin County, no moraine is mapped (Goldthwait, 1958b), but the edge of the ice which deposited this moraine is interpreted to have extended to the north-northwest, partly west of this ridge and partly in Black-

Figure 44. - Wisconsin-age Canal Winchester end moraine. View is toward the west, $1\frac{1}{2}$ miles southwest of Pickerington (NE$\frac{1}{4}$, sec. 21, Violet Twp.)

lick Creek valley, so that it is considered to meet the southern extension of the New Albany moraine (mapped by Goldthwait, 1958b, and named by Forsyth in Root, Rodriquez, and Forsyth, 1961, p. 126).

Where the Canal Winchester moraine is recognized in northwestern Violet Township, the morainic topography is subdued. To the south, however, between Pickerington and Canal Winchester, the moraine has a definite crest rising as much as 40 feet above the general level of the land and is characterized by relatively strong hummocky topography with kettle holes. A small field of kames 2 miles west of Pickerington seems to relate both to this moraine and to a series of sand and gravel ridges extending along a line that trends southeastward across eastern Franklin County. These ridges were mapped as segments of an esker by Goldthwait (1958b). Apparently, at the time when ice was depositing the Canal Winchester moraine, gravel was also accumulating in an ice tube originating far to the northwest of Fairfield County. Thus, the esker ridges, the kames, and the Canal Winchester moraine are all features which were deposited simultaneously, at the time when the ice edge stood at the moraine.

South, east, and southeast of Canal Winchester, the moraine becomes lower and its topography becomes more subdued. The moraine is broken by the valley of Walnut Creek and then ends against the northern foot of Chestnut Ridge. From Pickerington south to Chestnut Ridge, the pattern of the moraine is that of a broad arc, convex to the east. This represents the outline of the ice sub-lobe that must have pushed eastward up the old preglacial Groveport River valley.

Presumably the ice edge represented by the Canal Winchester moraine extended on around the base of Chestnut Ridge to the west and south, but no equivalent end moraine is recognized anywhere farther south in Fairfield County. Based on the distribution of the shallower (Miami 6A) soils (see p. 132 and fig. 42), which are mapped west of the Canal Winchester moraine in Violet Township, in the northeastern corner of Pickaway County, and in sections 7 and 18 of Amanda Township, this moraine is believed to correlate with the moraine which lies east of Circleville. This is the moraine called the Marcy by Stout (Stout, Ver Steeg, and Lamb, 1943), by Schuster (1952), and by Goldthwait, White, and Forsyth (on the "Glacial Map of Ohio", 1961). On the basis of the distribution of the Miami 6A and Miami 60 soils farther west (fig. 43), the Canal Winchester moraine is also correlated with the Reesville moraine to the west, in Clinton County.

Soils on the Canal Winchester moraine are leached to an average depth of about 38 inches and are mapped in the Alexandria catena by soils scientists. To the west of the moraine, however, soils are "heavier" (contain more clay in the B horizon) and shallower, having a depth of leaching of only about 25 inches, and are mapped as Miami 6A soils. This change in the nature of the soil is attributed to a change in the nature of the parent till. To the west, the lime content of the till is higher because of the presence of limestone bedrock over which the advancing glacier moved; to the east, on the Canal Winchester moraine, the lime content is much lower, because of the addition of more sandy material from the local bedrock. As a result of the increase in sand in the till, the resulting soil tends to be deeper and to contain less clay in the B horizon (see p. 126).

YOUNGER WISCONSIN SOILS

Throughout most of Fairfield County, the upland soils developed in Wisconsin till belong to the Alexandria catena; these soils, together with the suggestion that a somewhat earlier, deeper Alexandria soil may be present near the Wisconsin boundary, have already been discussed under "Older Wisconsin Soils" (p. 126). Along the western edge of the county (pl. 2 and fig. 42) are some different soils, the Miami 60 and Miami 6A. These are distinquished from the Alexandria soils by having greater amounts of clay in the B horizon, shallower depths of leaching, and much higher percentages of lime in the parent till (table 5). The lime, which is in the form of clay-, silt-, sand-, and pebble-sized fragments of limestone, is present because the glacier which deposited these lime-rich parent tills had just passed over an extensive outcrop of limestone and had not yet reached far enough east to acquire a significant content of sandstone. Though these lime-rich Miami soils may have a somewhat greater clay content than the Alexandria soils, the amount of clay in the B horizon, compared with that in the C horizon, is markedly higher in the Miami soils. This means that more clay is created by weathering and is accumulated in the B horizon in the Miami soils than in the Alexandria soils. Apparently, clay formation is greater in soils which contain higher percentages of lime. As a result of the extra lime and probably also because of the higher percentage of clay in the B horizon, depths of leaching are more shallow. Greater concentrations of lime take longer to remove, and higher percentages of clay impede the movement of the ground water which accomplishes the leaching.

Of the two Miami soils, the Miami 6A has a much shallower depth of leaching than the Miami 60 (20-27 inches compared with 24-37 inches) and has more clay in the B horizon (40-50 percent compared with 33-45 percent) (table 5). Because, farther west in Ohio, the line between these two Miami soils generally follows the boundaries of an end moraine, and because this line is fairly sharp, these two soils are considered to represent two separate drifts of different ages, the Miami 6A soil having developed in the younger till.

On the other hand, the line between the Miami soils to the west and the Alexandria soils to the east does not separate drifts of different ages. Rather, it represents the position, along the line of the glacial advance from west to east, where the contribution of Fairfield County sandstone has so modified the nature of the till that the characteristics of the resulting soil are no longer those of the Miami catena (figs. 42 and 43 and table 5). These soils, which are called Alexandria, are typified by having less lime in the C horizon, less clay in the B horizon, and a greater depth of leaching than either of the Miami soils (table 5).

Because the tills in which the Miami 60 and Miami 6A soils are developed are believed to be of different age, the line between them represents the outer boundary of a glacial advance. Most of the till of this later advance is lime rich, with the result that Miami 6A soils are generally present in the area of this later advance. In places, however, this advance passed over sandstone outcrops, which so modified the resulting till that, in these areas, Alexandria soils rather than Miami 6A soils are present. This is what happened on the Canal Winchester moraine, which dates from this later glacial advance. Alexandria soils and not Miami 6A soils are observed on this moraine in Fairfield County (north from the town of Canal Winchester), and also in a number of other counties to the north. The older glacial advance shows a similar pattern. Till deposited by this advance has Miami 60 soil developed in it near the western margin of the county, where lime still dominates the till, but is characterized by the presence of Alexandria soils elsewhere in the county. These Alexandria soils associated with the Miami 60 soil seem to be generally somewhat deeper and to have an appearance of greater weathering than the Alexandria soils which occur with the Miami 6A soils. Thus, the younger till has both Miami 6A and shallower Alexandria soils developed in it, while the older till has developed in it both Miami 60 and deeper Alexandria soils. The line separating these two ages of till and their associated soils is shown in figure 42 as being present in the following areas of western Fairfield County (and eastern Pickaway County): (1) in eastern Pickaway County, west of the Fairfield County boundary, opposite the area of Miami 60 soils in Clear Creek Township of Fairfield County; (2) to the west, along the line separating the Miami 6A and Miami 60 soils in western Amanda Township; and (3) in the northwest, within the area mapped Alexandria, probably at or near the east edge of the Canal Winchester moraine. A similar line has been observed two counties to the north, in Knox County, along the eastern edge of the New Albany moraine, a correlative of the Canal Winchester moraine. There, this line has been shown to separate a shallower Miami 6A equivalent Alexandria (Centerburg) soil from a deeper Miami 60-equivalent Alexandria (Mount Liberty) soil (see Root, Rodriquez, and Forsyth, 1961).

All these different soils and their relationships, as mapped and discussed here and as they occur throughout southwestern Ohio, are accepted by soils scientists. Indeed, most of the research and evaluation which led to this understanding was theirs. And the Miami 6A and Miami 60 boundaries in Fairfield County, as shown on plate 2 and in figure 42, were drawn by soils men (Meeker, Petro, and Bone, 1960).

GROUND MORAINE

Ground moraine in Fairfield County (pl. 2 and fig. 41) occupies much of the area between the end moraines, and is composed of till. Where bedrock protrudes through the drift as hills and knobs, the till is thin and may even be absent; elsewhere the drift is thicker, and along the preglacial Groveport and Logan buried valleys, it reaches its maximum thickness. Representative depths of drift in the Groveport buried valley are as follows: (1) more than 100 feet between the Rushville and New Salem moraines, (2) about 50 feet between the New Salem and Johnstown moraines, and (3) about 100 feet between the Johnstown and Canal Winchester moraines. Where the thickness is so very great, the drift is usually composed not only of till but also of layers of sand and gravel, silt, and in some places, lake clay. In places throughout the county, the till of the ground moraine is mantled by thin lake or outwash deposits and, in a few small areas, by silt thought to be wind blown.

To the north and northwest in Fairfield County, where the drift is thick, the surface of the ground moraine varies from gently undulating to almost flat (fig. 45). Farther east and south, however, where the bedrock is closer to the surface, the ground-moraine topography becomes quite hilly. These hills reflect with little modification the underlying bedrock surface and lack the hummocks which characterize true end moraine. In the areas of these hills, ground moraine is mapped wherever a thin deposit of till mantles the bedrock surface, but areas of drift-free knobs of bedrock, which protrude up through the glacial deposits (fig. 46) are mapped separately (marked "U") on plate 2. This does not necessarily mean that the glacier

Figure 45. - Typical Wisconsin ground moraine in area of thick drift, within the area of the deep buried Groveport valley. View is toward the east, 4 miles west of Basil (Baltimore) (SE$\frac{1}{4}$, sec. 19, Liberty Twp.).

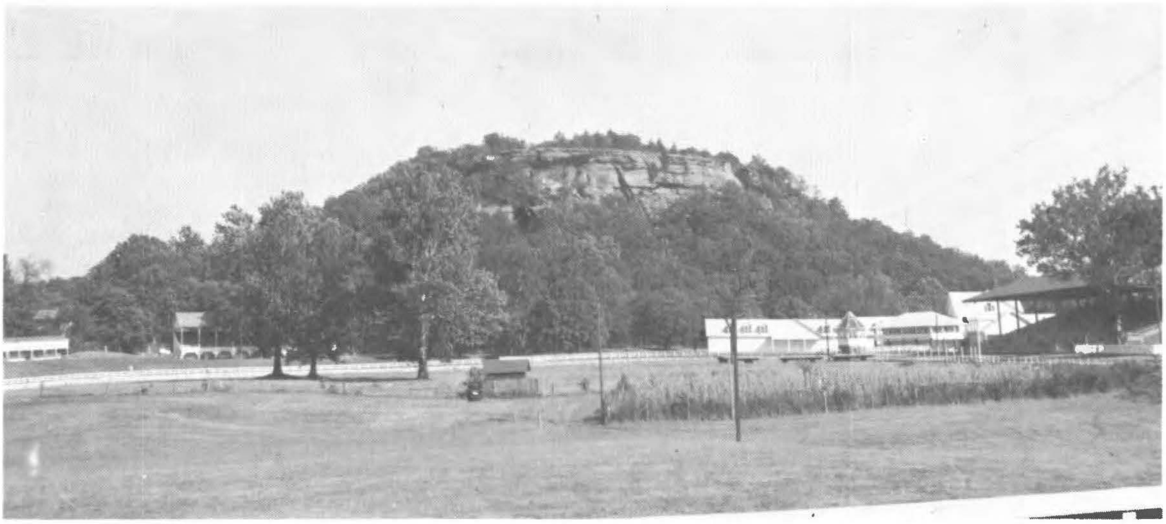


Figure 46. - Mt. Pleasant, an example of a bedrock knob projecting out through Wisconsin-age drift. The knob, which is located in the northern part of Lancaster, is capped by Mississippian-age Black Hand sandstone. View is toward the east, across the county fairgrounds.

never covered these bedrock knobs, but simply indicates the lack of any glacial cover today. Most of the knobs lie in the following areas, where the till mantle is thin or absent: north of Lancaster, southwest of Lancaster, on Chestnut Ridge, northeast of Amanda, and south of Oakland (southeastern Clear Creek Township).

Soils developed in the tills of the ground moraine are similar to those developed in the tills of the associated end moraines. Between the Rushville and New Salem moraines, the soils belong to the Alexandria catena and are leached to a depth of from 42 to 60 inches (Conley, 1956, pl. II). Alexandria soils are also present between the New Salem and Johnstown moraines, where depths of leaching generally range from 38 to 45 inches (Conley, 1956, pl. II), and west of the Johnstown moraine. In both the southwestern corner of the county and in the area near and north of Cedar Hill, as well as near Canal Winchester, Miami soils are present which are shallower and are leached to depths of from 20 to 37 inches.

Distribution of erratic boulders is significant in some areas of Fairfield County. The symbols shown on the boulder map (fig. 47) of Conley (1956) indicate that, though erratic boulders generally are distributed throughout the areas of Wisconsin drift, the only areas where they are especially abundant are on the end moraines where the drift is thick, as for example, on the Rushville moraine north of Oakthorpe and on the Johnstown moraine north of Baltimore. Boulders are fairly abundant in ground moraine characterized by thick drift, as in Clear Creek and Violet Townships, and are less common in the areas of abundant bedrock hills. Unfortunately, these erratic boulders do not reveal any clear beltlike arrangement.

KAMES AND ESKERS

Kames occur in a number of widely separated localities in Fairfield County (fig. 48), associated with almost every end moraine (pl. 2 and fig. 41). Though all the kames are hills of gravel, the gravel varies in composition and quality and in the presence or absence of a silt cap.

In only three places do hills of sand and gravel occur in such a linear pattern as to be mapped as eskers. The largest and most characteristic of these eskers lies east of Pickerington (fig. 49). Of the other eskers, the one located a quarter of a mile north of Cedar Hill is so short that only its distinct linearity prevents it from being mapped as a kame. The third esker occurs a quarter of a mile west of Carroll, in association with the Carroll kame terrace, and appears to be an integral part of that gravel complex. Many of these kames and eskers have not been excavated, so the nature of the material composing them has had to be inferred from topographic characteristics and from data supplied by the new soils map of the county (Meeker, Petro, and Bone, 1960). On the following pages, the kames and eskers associated with each of the morainal belts will be considered separately in detail.

KAMES ASSOCIATED WITH THE RUSHVILLE MORAINE

Kames associated with the Rushville moraine are present near Oakthorpe, in the eastern part of the county; in a few localities in the hills north of Lancaster; and (by tentative correlation) among the hills 3 miles east of Amanda. The kames near Oakthorpe are quite extensive, but have been utilized for sand and gravel only to a minor degree. North of Lancaster, only two kames have actually been identified and these are small. Because the kames in both these areas lie among hills of shale

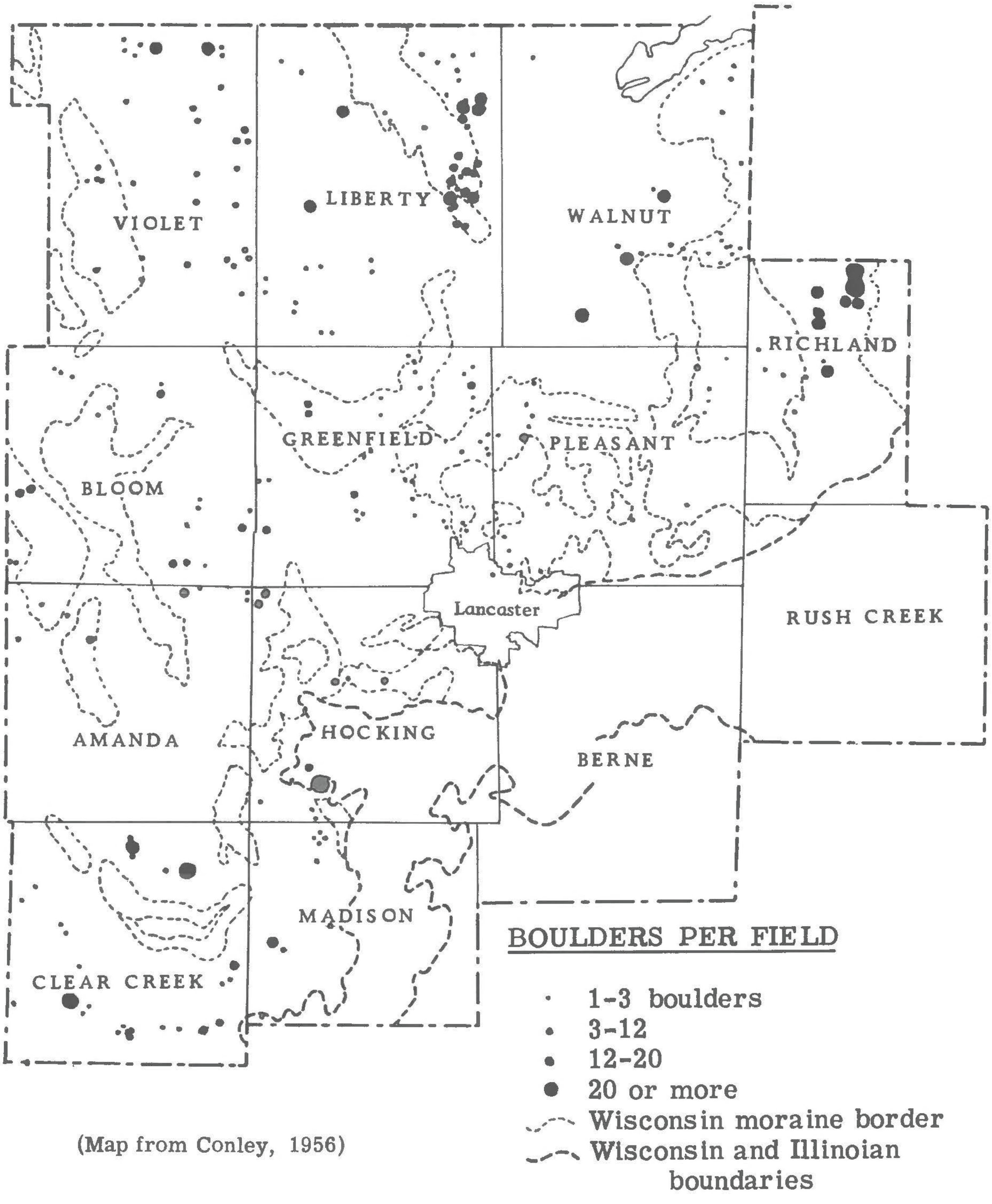


Figure 47. - Map showing distribution of erratic boulders in Fairfield County.

Figure 48. - Wisconsin kames, 3 miles east of Amanda (SW$\frac{1}{4}$, sec. 29, Hocking Twp.). View is toward the southwest.

Figure 49. - View of the Wisconsin-age Pickerington esker, which underlies State Route 256, about 3 miles east of Pickerington (NE$\frac{1}{4}$, sec. 13, Violet Twp.). Note gentle slopes down to the left (south) and right (north) sides of the esker. The slopes are more apparent when contrasted with the vertical walls of the buildings on either side of the road.

and sandstone, the gravel in these kames is likely to contain a relatively high percentage of deleterious materials (fragments of sandstone, siltstone, or shale which tend to break up easily and are allowed in only very small amounts by limitations of the State gravel qualifications). The gravel in both these areas is probably also less well sorted than that in the younger kames farther to the west. In addition, in many places it is capped by silt, which increases the thickness of the overburden and therefore the cost of removing the gravel.

The soils formed in these deposits are better developed and deeper than those to the west. The B horizon is dark brown and deep, but generally does not develop the pendant-type structures characteristic of shallower gravel soils. Dolomite and limestone pebbles originally present in this zone are completely weathered, so that only "ghosts" remain. Carbonates are leached to a depth of as much as 80 inches below the surface, the greater values usually occurring where the capping silt is thickest.

The kames east of Amanda occur as steep-sided hills (fig. 48), which usually indicate the presence of relatively coarse gravel. No silt cap has been observed here. However, because of the proximity of bedrock hills, a fair percentage of deleterious materials is also likely to be present here.

KAMES ASSOCIATED WITH THE NEW SALEM MORAINE

Kames associated with the New Salem moraine occur 3 miles east of Millersport (just south of Buckeye Lake) and 4 miles southwest of Lancaster. A single kame 2 miles northeast of Amanda may also be related to this stage of glaciation. The kames east of Millersport, which have been partly excavated, occur as fairly steep-sided hills within the area of end moraine. The kames 4 miles southwest of Lancaster are also apparently of the same age. However, the identification of these kames is confused by the presence of local minor patches of end moraine, of silt areas, and of bedrock hills which protrude through the drift and which probably had a considerable effect on the advancing ice. These kames lack typical kame-type topography and are therefore believed to contain only limited amounts of gravel, with significant additions of silt and sand. Therefore, it is questionable whether there are any economic gravel deposits in this area. The nature of the material in the kame 2 miles northeast of Amanda is not known because there has been no excavation there.

KAMES AND OTHER GRAVEL DEPOSITS ASSOCIATED WITH THE JOHNSTOWN MORAINE

There are more and better gravel deposits associated with the Johnstown moraine than with any other moraine in Fairfield County. These include a high area of kames southeast of Carroll, some minor kames farther south in the hills, an extensive kame terrace and esker west of Carroll, and an esker to the north. The kames southeast of Carroll occur within the area of the Johnstown end moraine, mostly along its crest just east of U. S. Route 33. There are no exposures in these kames, so the nature of the gravel is not known. Because the kames are intimately associated with the crest of the end moraine, sorting is probably rather poor; large cobbles are probably common and masses of till are also likely to be present. A few local kames associated with this ice edge also occur farther south among the bedrock hills; these have not been excavated, so the nature of their contents is not known.

The Carroll kame terrace, located immediately west of Carroll, is the largest single deposit of sand and gravel in the county. This feature lies on the southwest side of the preglacial Groveport River valley, on the lower slopes of Chestnut Ridge. To the east, it is bounded by the Johnstown moraine, to which it seems to be related. Apparently, the deposit represents the fill of sand and gravel laid down by glacial melt water channeled between the margin of the ice to the northeast (marked by the Johnstown end moraine) and the bedrock hill to the southwest. The terrace is composed of stratified sand and gravel which is generally fairly coarse. The presence of occasional small blocks of coarse sandstone (Conley, 1956, p. 50), some of which measure as much as 24 inches across, suggests that deleterious materials would probably make up at least a moderate percentage of the gravel, though probably not to the extent found in the older kames near Oakthorpe, Lancaster, and Amanda. The surface of the kame terrace, where not altered by erosion, in places contains kettles, indicating proximity of ice during deposition. This surface slopes to the southeast, merging with that of the Carroll outwash terrace, the lower of the two Wisconsin constructional terraces in the Hocking River valley. Thus, the Carroll kame terrace and, therefore, also the Johnstown moraine seem to mark the position of the ice edge when the Carroll outwash terrace was being deposited. On the northeast side of the kame terrace, close to and parallel to the main highway (U. S. Route 33), is a long narrow hill oriented northwest-southeast. The gravel composing this hill seems to be the same as that in the rest of the kame terrace, but because of its linearity, the hill is mapped as an esker. Though doubtless (from its shape) formed in a channel or tunnel in the ice, this esker, because of its proximity to the kame terrace, must have been deposited very near to the margin of the glacier.

One of the most interesting gravel deposits in the county is the ridge of sand and gravel which follows, and in most places underlies, State Route 256 between Pickerington and Baltimore. This ridge, called the Pickerington esker (fig. 49), was recognized first by Leverett (1902, p. 428-429) and later by Hyde (1912, p. 222), who named it. It begins in Pickerington as an elongate hill of gravel on the west bank of Sycamore Creek and extends eastward as a low discontinuous winding ridge to approximately a mile northwest of Basil (Baltimore), where it terminates just west of the Johnstown moraine. The ridge is from 6 to 10 feet high, 60 to 130 feet wide, and is composed of stratified sand and gravel, with deposits of fine sand occurring in the low flats along either side.

The gravel deposits associated with the Johnstown moraine generally lack a silt cap. Fox soils are developed in them, characterized by pendants of red B-horizon material extending downward into the unweathered gravel below. The deposits generally are leached of carbonates to about 50 inches below the surface, though the pendants locally may extend deeper by as much as 3 feet or more.

KAMES ASSOCIATED WITH THE CEDAR HILL MORAINE

Kames associated with the Cedar Hill moraine occur east of Marcy and south of Cedar Hill. The low kames northwest of Cedar Hill, called the Walnut kames, are not included in this group of deposits because they are considered to be younger; they are discussed below, under "Kames Associated with the Canal Winchester Moraine." The kames east of Marcy occur within and along the crest of the Cedar Hill moraine in much the same manner as the kames along the crest of the Johnstown moraine southeast of Carroll. Though minor excavation has taken place locally in these hills in the past, their contents are not exposed at the present time. A short distance south of Cedar Hill is a large kame which seems to represent the place where the Cedar Hill ice edge bent around from an almost north-south orientation to an east-west orientation, so that south of Cedar Hill the ice edge must have stood along the south side of

Turkey Run valley. Because there are no excavations in this kame, the nature of its contents is not known.

KAMES ASSOCIATED WITH THE CANAL WINCHESTER MORAINE

Kames related to the Canal Winchester moraine include those west of Pickerington, those east of Waterloo, and also those northwest of Cedar Hill called the Walnut kames. Because of their position adjacent to the Canal Winchester moraine, the kames west of Pickerington are considered to be related genetically to the moraine, both features being related to the same position of the ice edge. The kames also seem to correlate with a long, discontinuous esker recognized in Franklin County by Goldthwait (1958b). This esker consists of widely separated segments which Goldthwait traces for about 15 miles from north to south across the eastern part of Franklin County. The southernmost segment lies near Brice, 3 miles northwest of the kames near Pickerington, and seems to be headed toward these kames. Eskers represent glacial gravel deposited under ice, and kames represent glacial gravel deposited at the crevassed, melting margin of the ice. Thus, it is believed by Goldthwait and by the author (Forsyth) that, when the ice stood at the Canal Winchester moraine, gravel was being accumulated both in the ice tunnel far back to the north and along the crevassed margin of that ice near the place where the drainage from the ice tunnel emerged.

The kames east of Waterloo are located in and near the valley of Walnut Creek, in association with the Canal Winchester moraine. Thick silts are associated with the gravel here and suggest that a variety of depositional environments were present along the ice edge at that time. The kames northwest of Cedar Hill lie in both Fairfield and Pickaway Counties and were named the Walnut kames by Schuster (1952, p. 44-47). These kames are considered to correlate with the Canal Winchester moraine and adjacent kames because both occur in association with Miami 6A soils (see p. 132). The kames are composed of sand and gravel and exhibit irregular, locally steep bedding such as that which occurs characteristically in kames. Conley (1956, p. 52) believes that their crestlines are elongate and at right angles to the former ice edge, with a suggestion of an echelon pattern. He suggests that these deposits may be crevasse fillings.

OUTWASH TERRACES

The main occurrence of Wisconsin outwash terraces in Fairfield County is in the Hocking Valley, which contains two distinct constructional terraces (fig. 50) and a lower erosional, or "cut" terrace (Kempton, 1956; Kempton and Goldthwait, 1959).

LANCASTER TERRACE

The upper, or older of the two constructional terraces heads at Lancaster, just within the Wisconsin boundary. For this reason, it is called the Lancaster terrace. It underlies much of the city of Lancaster, where it occurs at an elevation of 847 feet, and also forms the broad flat that lies east of the city, where it has been excavated for gravel. Farther east, across Pleasant Run, this same terrace level is present, underlain by slack-water silts, finer materials of mostly local origin,

Figure 50. - Wisconsin constructional terraces. View is toward the north along the west side of the Hocking Valley, 1 mile northwest of Clark Crossing (NE$\frac{1}{4}$, sec. 20, Berne Twp.). The broad level dominating the picture is the Lancaster terrace; the lower level visible indistinctly back to the right is the lower, Carroll terrace.

which accumulated in Pleasant Run valley behind the dam of glacial gravels in the Hocking Valley (see p. 144). Small remnants of the higher outwash terrace also occur across the Hocking Valley from Lancaster. From Lancaster, this terrace may be traced southward, down the Hocking Valley. The next area of extensive terrace remnants is near Clark Crossing, where the terrace is present on both sides of the river at 798 feet elevation (fig. 50). The terrace remnant on the west side of the river is small, but the terrace on the east side is fairly extensive, being present east of Clark Crossing as far as Rush Creek and then south along Rush Creek valley to Sugargrove. Here it is at an elevation of 792 feet.

The gradient of the terrace throughout the entire length of its occurrence in Fairfield County is about 7 feet per mile, though near Lancaster it steepens to almost 16 feet per mile (Kempton and Goldthwait, 1959, p. 140).

Conley (1956, p. 61) reports that small remnants of this terrace, which he believes to be defended by bedrock, are found in places along the sides of the Hocking Valley (including the location at the mouth of the unnamed tributary which enters the Hocking River from the east, just south of Sugargrove). Farther south down the Hocking Valley, beyond the Fairfield County line, this terrace may be traced all the way to the Ohio River (Kempton, 1956; Kempton and Goldthwait, 1959).

The Lancaster terrace is composed of sand and gravel, which where not eroded, is covered by silt that is generally 2 to 3 feet thick. The soil developed in this terrace is the deep Ockley (once called Rush) soil, which is characterized by a deep, chocolate-brown B horizon. Pendant-type structures, such as occur at the base of the B horizon in shallower gravel soils elsewhere, are lacking in these deposits. The soil is leached of carbonates to depths of from 60 to more than 90 inches.

The age of this terrace has been a matter of controversy. Its relative elevation is well below that of the Illinoian terrace, but distinctly higher than that of the other Wisconsin constructional terrace. The soil profile, with its thick silt cover, is deep, but lacks the appearance of really intensive weathering characteristic of Illinoian soils. As a result, on the basis of its relative elevation, the depth and nature of its soil profile, the presence of its silt cap, and its regional distribution, the terrace is believed to be of "early" Wisconsin age (see Forsyth, 1957a, 1957b; also Kempton, 1956; Kempton and Goldthwait, 1959, p. 149).

CARROLL TERRACE

The lower Wisconsin constructional terrace, which is called the Carroll terrace, begins just south of the Carroll kame terrace, to which it seems to be related genetically, apparently representing the downstream extension of that deposit. The terrace surface slopes uniformly downstream to the south from the kame terrace. Small kettle holes, which are present in the more northern part of this terrace (Conley, 1956, p. 62), indicate that glacial ice must have stood close to that part of the terrace while it was being deposited. Indeed, from the close relationship of the Carroll terrace, the Carroll kame terrace, and the adjacent Johnstown moraine, it is evident that all three features were deposited at the same time, when the ice stood at the Johnstown moraine.

North of Lancaster, the surface of the Carroll terrace ranges in elevation from 875 feet at Columbia Park to 857 feet below Hooker, and has a maximum gradient of about 10 feet per mile. South of Lancaster this deposit, which here becomes the lower of the two Wisconsin constructional terraces, ranges in elevation from 812 feet just south of Lancaster to 782 feet opposite Sugargrove, representing a more gentle gradient of about 5 feet per mile.

The soil which is developed in this lower terrace is called the Fox soil, deep phase. It is shallower than the soil on the older, higher terrace and lacks the silt cap. The B horizon, which is characterized by conspicuous pendant structures, is brownish red and generally is leached of carbonates to a depth of about 50 inches.

"CUT" TERRACES

Lower terraces created by erosion of these older, higher constructional terraces are present in a number of places along the Hocking Valley. These erosional, or "cut" terraces are usually composed of the glacial gravels of the constructional terrace from which they were eroded and are capped by younger silty alluvium. In some places this alluvium is many feet thick; in others it is thin or absent. At one locality, in section 17 of Berne Township, 3 miles southeast of Lancaster, the underlying gravel is so close to the surface that the gravel may be exploited. The largest remnants of the cut terrace are found at the following localities: across the Hocking Valley from Lancaster, at 825 feet elevation; in section 17 southeast of Lancaster, at 815 feet elevation; across from Clark Crossing, at 795 feet elevation; and at the Fairfield-Hocking County line, at approximately 760 feet elevation.

TERRACE CORRELATION

It is of interest to note, at this point, that a sequence of two constructional terraces above a lower, cut terrace is reported also from Licking County (Jones, 1959) and from Knox County (Root, Rodriquez, and Forsyth, 1961). However, the higher constructional terraces in Knox and Licking Counties, which are capped by silt, seem to correlate, on the basis of their relationship to the Johnstown moraine, with the lower of the two constructional terraces in Fairfield County (see Root, Rodriquez, and Forsyth, 1961, p. 134). The lack of silt on this lower terrace in Fairfield County may represent the lack of adequate amounts of wind-blown silt from the Pleistocene flood plains to the west, or it may be due to the height of the intervening tree-covered uplands which could have filtered the silt out of the air before it reached the Hocking Valley. The lower terraces in Knox and Licking Counties can be traced back to the New Albany moraine, a northern correlative of the Canal Winchester moraine. No terrace related to the Canal Winchester moraine could be expected in Fairfield County, because the outwash from this moraine did not go down the Hocking Valley, but was carried southwestward into the Scioto drainage. No "early" Wisconsin outwash is recognized in Licking or Knox Counties.

OTHER WISCONSIN TERRACES

Outwash terraces are also present near Clearport and northwest of Pickerington in Blacklick Creek valley (Conley, 1956, p. 63, 64). Only one level of terrace has been identified in each of these areas. Because the relationships of these surfaces to the well-defined terrace sequence in the Hocking Valley is not clear, no correlation is attempted and they are mapped simply as undifferentiated Wisconsin outwash terrace (Wo) on plate 2. In most places, these deposits are composed of sand and gravel which is poorly sorted (blocks of sandstone are reported by Conley, 1956, p. 64, to be present in the deposit northwest of Pickerington), shallow, and in many places mantled by a silty alluvial cap. The gravel in the terrace northwest of Pickerington is exposed in the pit of the R. and M. Sand and Gravel Co. which is located near the middle of the east boundary of section 19, Violet Township.

LAKE DEPOSITS

Poorly stratified Wisconsin lake silts and clays occur associated with every major Wisconsin end moraine in Fairfield County (pl. 2 and fig. 41). Lake deposits which date from the time of formation of the Rushville moraine are present in three areas: (1) in front of the Rushville moraine in a basin northeast of Oakthrope; (2) in the valleys between Lancaster and Bremen, and Bremen and Clark Crossing; and (3) in a few small narrow valleys in the hills north of Lancaster. Determination of the detailed outlines of these areas of lake deposits was greatly aided by the new soils map of the county (Meeker, Petro, and Bone, 1960).

Associated with the New Salem moraine are areas of lake deposits (1) east of Pleasantville, and (2) in the upper reaches of Pleasant Run, northeast of Lancaster. Probably belonging to this same generation of lakes are (3) the deposits at Greencastle, in front of the Lithopolis moraine, and also the lake deposits farther south, which include the areas (4) in central Hocking Township 4 miles southwest of Lancaster, (5) near Delmount 5 miles southwest of Lancaster, and (6) along Clear Creek between Amanda and Clearport (fig. 51).

Dating from the time when the ice stood at the Johnstown moraine are (1) the large area of lake deposits in the Buckeye Lake basin between Baltimore and Millersport, as well as smaller areas of lake deposits (2) east of Columbia Park, and (3) northwest of Baltimore (at a somewhat later stage).

Lake deposits associated with the Cedar Hill moraine occur (1) north and northwest of Amanda, and (2) west of Royalton. Lake deposits near Lockville Station appear

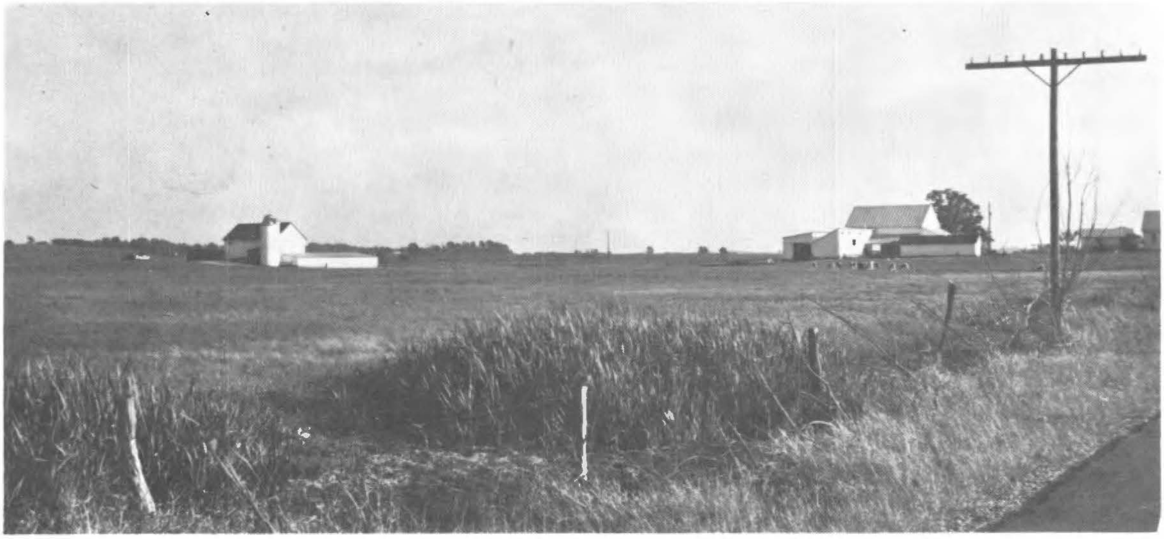


Figure 51. - View southwest across area of Wisconsin lake silts, $1\frac{1}{2}$ miles north of Amanda (NW$\frac{1}{4}$, sec. 25, Amanda Twp.). Note rushes in foreground, which are indicative of poorly drained lake bottom.

to correlate with the Canal Winchester moraine. Each of these areas will be discussed in detail below.

LAKE DEPOSITS ASSOCIATED WITH THE RUSHVILLE MORAINE

Most fascinating of all the areas of lake deposits are those associated with the Rushville moraine. The story of these lakes is the story of the evolution of modern Rush Creek. Rush Creek was originally a westward-flowing tributary of the Teays drainage system. It had been blocked first by a dam of Illinoian ice in the valley east of Lancaster, causing the drainage to find a new route. The new outlet, which became permanent, led to the south and then west through section 35 of Rush Creek Township, Fairfield County, and Marion Township of Hocking County, reentered Fairfield County in Berne Township and joined the Hocking Valley east of Clark Crossing. With the subsequent advance of the Wisconsin glacier, new lakes were formed in a number of places along the ice front. The upper reaches of Rush Creek, east of Oakthorpe (northeastern Richland Township), were dammed by the Rushville moraine and also, perhaps, by the ice itself. Drainage from this lake finally developed a new outlet which led southward from the east end of the basin through a gorge cut by the escaping waters just west of Redington in western Perry County (Flint, 1951, p. 6-7). The stream then turned west and entered part of its old valley again near Oakthorpe, only to turn abruptly south into another gorge, cut through the Rushville moraine at Rushville. Some of the lake deposits just north of the moraine here may also be of this age, accumulated in a lake held in by this moraine. The waters emerged from this gorge at Bremen, where another, larger lake was formed by a dam of Wisconsin glacial outwash (Lancaster terrace level) at Lancaster, Clark Crossing, and Sugargrove in the Hocking Valley. Glacial ice also may have contributed to this damming at some time. This lake occupied the valley between Lancaster and the county line east of Bremen, including the valleys of both Little Rush Creek and Turkey Run, and also the valley of Rush Creek south of Bremen and east of Clark Crossing (much of this part of the lake lay in Marion Township of Hocking County).

The small, narrow areas of lake deposits in the valleys of Fetters and Ewing Runs in the hills north of Lancaster probably date from this time also.

LAKE DEPOSITS ASSOCIATED WITH THE NEW SALEM AND LITHOPOLIS MORAINES

The largest area of lake deposits associated with the New Salem moraine lies east and southeast of Pleasantville, at the northwestern foot of the Rushville moraine. This lake drained to the south through the Rushville gorge in the Rushville moraine. The little area of lake deposits northeast of Lancaster, at the upper end of Pleasant Run in sections 9, 10, and 15 of Pleasant Township, also appears to relate to the New Salem moraine.

The long narrow area of lake deposits near the town of Greencastle, extending eastward in central Bloom Township from the Lithopolis moraine, is believed to correlate with the New Salem moraine. It represents the deposits accumulated in a northwest-flowing stream which has since been reversed so that the present outlet is to the east through Rock Mills.

Other deposits interpreted to be of the same age are found 4 miles southwest of Lancaster in section 23 of central Hocking Township, 5 miles southwest of Lancaster in a small narrow area near Delmount, and in the broad flat area along Clear Creek between Amanda and Clearport (fig. 51). All these areas of lake deposits represent shallow, temporary bodies of water at or near the Wisconsin boundary. Drainage from the lake in central Hocking Township finally eroded an outlet to the south, creating a long narrow channel now occupied by Arney Run, which joins the main valley of Clear Creek at a point 1 mile east of Clearport. The lake at Delmount, which lay up against the hills of bedrock thinly capped by Illinoian drift, also eventually developed a narrow outlet channel through the hills to the southeast. This channel became permanent and is now occupied by the headwaters of Arney Run. Clear Creek itself originally flowed westward, but was blocked by the advancing Wisconsin ice (and possibly also by the earlier Illinoian ice), so that reversal took place, but not before a rather broad expanse of area in sections 7 and 8 of Madison Township and also section 12 of Clear Creek Township had received a veneer of Wisconsin lake deposits.

LAKE DEPOSITS ASSOCIATED WITH THE JOHNSTOWN MORAINE

The largest area of lake deposits in the county occurs in the Baltimore-Thurston-Millersport area, just east of the Johnstown moraine and in the Buckeye Lake basin, all of which lies in the partially filled valley of the old westward-flowing Groveport River of Teays age. The lake that occupied the Buckeye Lake basin during glacial times was much larger than the present artificial lake, which was created in 1832 to supply water for the Ohio Central Canal (Conley, 1956, p. 5).

Logs of water wells drilled along the southern shore of the present lake record a stratigraphic succession of silt and clay at depth, overlain by gray till, which in turn is overlain by silt and clay at the surface. This stratigraphic sequence indicates that another lake, recorded by the underlying clay and silt, once existed in this basin. The lake probably was drained before the advance of the last Wisconsin glacier, whose presence is indicated by the gray till as shown in the logs. Damming by this glacier and the Johnstown moraine produced the final lake, whose deposits of silt and clay are seen above the gray till in the well logs and are also exposed at the land surface. This lake finally found an outlet to the east which led by the present village of Thornville Station to the valley of Jonathan Creek. Jonathan Creek valley, which narrows to the east, is believed to have contained originally a westward-flowing stream. Because of the dam of ice and moraine to the west, the original stream became ponded and then was reversed. Aided by the great volume of escaping melt water, the stream lowered the ancient col on the east to such an extent that the reversal became permanent, creating the present Jonathan Creek (Flint, 1951, p. 6).

The lake deposits east of Columbia Park lie in sections 15, 16, 21, and 22 of Greenfield Township and represent deposits accumulated in a shallow lake produced when the Johnstown moraine (and ice?) created a shallow basin at the foot of the high bedrock area west of Dumontville.

The lake deposits which form a long northwest-southeast belt northwest of Baltimore apparently represent deposition in a lake that developed shortly after the ice front had retreated from the position of the Johnstown moraine just to the east. An area of northwest-southeast-oriented sub-morainic topography in sections 8, 9, 16, and 17 of Liberty Township may represent the position of the ice at that time or may actually represent part of the dam that created the lake. In the northern part of section 22 and the western part of 23, a low rise probably related to the Pickerington esker contributes to the dam, but there is nothing in the present topography in the eastern part of section 23 to hold back a lake, so ice must still have been present at Baltimore when this lake was in existence. Thus, it must date from the initial stage of ice retreat from the Johnstown moraine.

LAKE DEPOSITS ASSOCIATED WITH THE CEDAR HILL MORAINE

The lake deposits north and northwest of Amanda, which lie in parts of sections 20 through 23 and 25 through 29 of Amanda Township appear to have been deposited in a lake formed when a westward-flowing stream was blocked by the Cedar Hill end moraine and kame. This westward-flowing stream consisted of the upper end of Clear Creek, and two of its tributaries--an unnamed tributary heading in section 14, and Muddy Prairie Creek heading in section 24, both of which join Clear Creek in section 22. This stream apparently flowed west near or just south of the town of Cedar Hill to join Turkey Run before being blocked by the Cedar Hill end moraine. The large kame south of the town of Cedar Hill seems to be located directly on the old route of this stream. When the lake was formed, its overflow found an outlet to the south and west around the south side of Amanda, becoming at that time a part of the present Clear Creek drainage.

At the northern headwaters of the upper end of Clear Creek, west of Royalton, in parts of sections 3, 4, 9, and 10 of Amanda Township, is another small area of lake deposits. These represent materials accumulated in a small lake created when the Cedar Hill moraine blocked the westward flow of minor drainage from the area west of Royalton.

LAKE DEPOSITS ASSOCIATED WITH THE CANAL WINCHESTER MORAINE

Poorly bedded silts ranging in thickness from 3 to 10 feet (Conley, 1956, p. 69) are present along the margins of Big Walnut Creek near Lockville Station. These silts were probably deposited in a lake formed when the westward drainage was blocked by the Canal Winchester moraine or by the ice which created this moraine. Drainage was restored when the escaping lake waters had cut an outlet to the west through the moraine. Hummocks in the ground moraine in the area of this old lake bed are not covered by silt, so the lake must have been quite shallow (Conley, 1956).

BURIED SOIL HORIZON

Conley (1956) has observed a buried soil, which he believes to be a paleosol, at a number of localities in Fairfield County. He reports that the typical stratigraphic section in these exposures consists of calcareous till at the surface, underlain by calcareous gravel, at the top of which is locally developed an oxidized, leached, and clay-enriched zone very similar to the B horizon of a modern Fox soil developed in gravel, with pendant structures extending down into the unweathered gravel. At no place did he observe a buried A horizon, but because of its silty nature, it could easily have been removed by the advance of the glacier which deposited the overlying till.

The locations at which Conley (1956, p. 79-84) observed the buried soil are (fig. 52): (1) in road cut along south side of State Route 104, in the west-central part of section 21, in northern Violet Township; (2) in abandoned borrow pit along the north side of U. S. Route 33, 1 mile east of Lockville Station and 2 miles north-northwest of Carroll, in the NW$\frac{1}{4}$ of section 35, Violet Township; (3) in cut along Poplar Creek 5 miles northwest of Baltimore, in the SE$\frac{1}{4}$ of section 8, Liberty Township; (4) in stream cut along Clear Creek 2$\frac{1}{2}$ miles north-northwest of Amanda, in the SE$\frac{1}{4}$ of section 10, Amanda Township; (5) in stream cut along the east bank of a tributary to the Hocking River from the south, 5 miles west-northwest of Lancaster, in the NE$\frac{1}{4}$ of section 31, Greenfield Township; (6) in gravel pit 1$\frac{1}{2}$ miles west-northwest of Dumontville, in the NW$\frac{1}{4}$ of section 14, Greenfield Township; and (7) in road cut 2 miles south of Lancaster, in the SE$\frac{1}{4}$ of section 13, Hocking Township. In addition, an exposure (8) in an excavated bank back from the north side of U. S. Route 33, behind the Mt. Pleasant Bowling Alleys, just east of the Lancaster State Highway Garage, in section 36 of Greenfield Township, revealed a lens-shaped mass of non-calcareous weathered till within an exposure of calcareous till. To explain this lens, it is postulated that, as the last glacier pushed southward, it picked up masses of the soil just previously developed and incorporated them as lenses in its new deposit of till. No weathered gravel occurs in this section, but it is presumed that the weathering of the gravel in the exposures listed above and the weathering of the original till from which this lens of weathered till came may represent the same soil-forming interval.

Buried soils similar to these in Fairfield County have been found in a number of other places in southern and southwestern Ohio. These have been interpreted by Goldthwait (1955) and Forsyth (1957a, 1957b) as representing the weathering during the interval separating "early" and "late" Wisconsin time; according to this interpretation, "early" Wisconsin time is considered to be post-Sangamon, but pre-classical Wisconsin.

This interpretation is not generally accepted. Leighton (1958, p. 306) suggests that the soil zone might actually record Sangamon time. Gooding, Thorp, and Gamble (1959) state that it is not a paleosol, but an extension at depth of the present surface soil, an interpretation which has been challenged by Goldthwait (1959) as ignoring sound evidence for true paleosols in some places.

As far as the weathered, leached zones in Fairfield County are concerned, however, this writer (Forsyth) believes that, though some of them are undoubtedly simply extensions at depth of the modern surface soil, others are true paleosols.

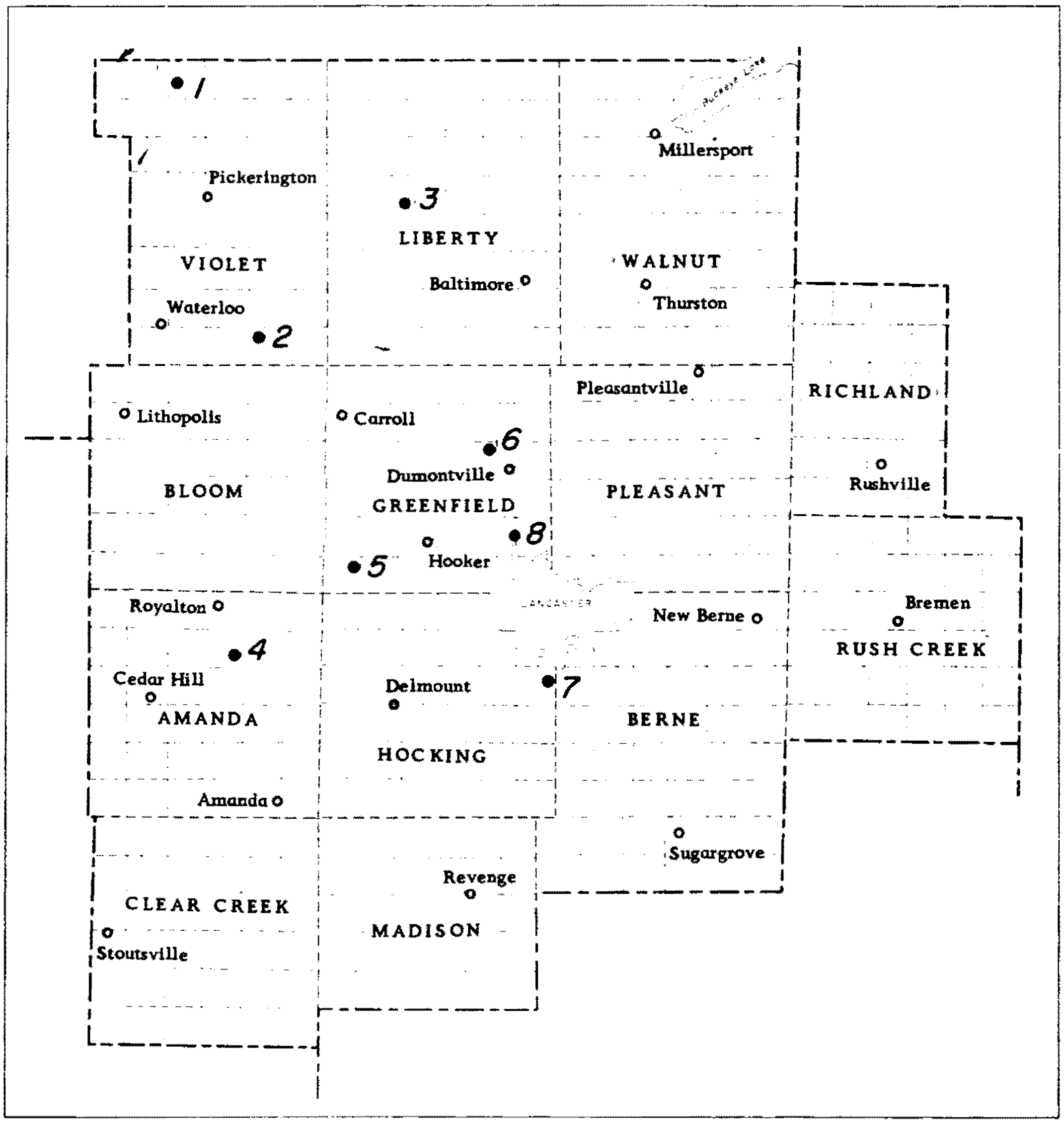


Figure 52. - Map showing localities where buried soil has been found in Fairfield County. Numbers refer to localities described in the text.

These paleosols represent soil developed in gravel of "early" Wisconsin age before the advent of the "late" Wisconsin glacier. The higher Wisconsin-age constructional terrace, the Lancaster, which is present only south of the Wisconsin boundary, is also interpreted to represent outwash from this same "early" Wisconsin advance. And, if the interpretation of Conley (1956) is correct, that the deeper soils near and on the Rushville moraine identify a drift that is distinctly older (as discussed on p. 126), it is possible that the older drift may also be of the same "early" Wisconsin age. It is also possible, however, that the older drift may be only of early "late" Wisconsin age, and not "early" Wisconsin age.

The age, in years, of this period of soil formation is not known. However, radiocarbon dates from other parts of central Ohio provide clues to this age. For example, near Gahanna, in a cut along Rocky Fork Creek in Franklin County, wood was found in the upper part of a gravel between two tills (though there was no paleosol developed in this gravel). Radiocarbon dating showed this wood to be>37,000 years old (W-263) (Goldthwait, 1955, p. 59, described the section, but the age given is incorrect, due to a typographical error; for the age of the wood, see Rubin and Suess, 1956). This gravel is believed to be equivalent to the gravel containing the buried soils in Fairfield County. If this correlation is correct, the gravel containing these buried soils is considerably older than classical Wisconsin, which is dated at no older than about 25,000 years in the classical area of the State of Illinois (Horberg, 1955).

Wood found in the overlying till outside (east of) the Johnstown moraine at Newark, in Licking County, was dated by the radiocarbon method as 21,400±600 (W-88) years old (Goldthwait 1955, p. 58; Suess 1954, p. 469). In downtown Columbus, excavation for the new Ohio Fuel Gas Co. building revealed a stratigraphic succession of till over gravel; wood from the base of the till was determined by radiocarbon dating to be 23,000±850 (Y-449) years old (Goldthwait, 1958a, p. 214). Other radiocarbon dates from wood taken from the base of the surface till throughout west-central Ohio (Goldthwait, 1958a; Forsyth, 1961) give similar values (25,000 to 17,000 years old).

In a stream cut along Brush Creek in Shelby County, in western Ohio, the author (Forsyth) found an exposure which contained two tills separated by a thin zone of alluvium and peat. A paleosol was developed in the top of the lower till. Wood from near the base of the upper till was dated at 22,000±1,000 (W-414) years, while the underlying peat was determined to be >37,000 years (W-415) years old (LaRocque and Forsyth, 1957, p. 81).

Radiocarbon dates from glacial deposits elsewhere in Ohio, therefore, suggest that the deposition of the "late" Wisconsin surface till in Fairfield County began about 21,000 years ago and lasted until the ice left the county, probably about 16,000 year ago (late Tazewell, or Bloomington time), and that the underlying gravel is more than 37,000 years old ("early" Wisconsin or pre-classical Wisconsin). According to this interpretation, the buried soil represents a period of soil development that lasted at least 17,000 years and probably more than 18,000 years.

Chapter 8

GROUND - WATER RESOURCES

By George D. Dove
Geologist, U. S. Geological Survey

GROUND WATER

GENERAL PRINCIPLES

The rocks[1] forming the crust of the earth are not solid throughout but generally contain numerous openings called voids or interstices. These openings may differ greatly in size, shape, arrangement, interconnection and continuity according to the character, distribution, and structure of the rocks in which they occur. The amount of water that can be stored in any rock depends chiefly upon the volume of open spaces in the rock. This porosity may be expressed quantitatively as the ratio of the interstitial volume of a rock to its total volume. When all the openings of a rock are filled with water, the rock is saturated. Therefore, the porosity of a saturated rock is equal to the percentage of its total volume that is occupied by water.

Only part of the water in a saturated deposit, however, can be withdrawn through wells and springs. Much of the water is held in the rock against the force of gravity by molecular attraction. The volume of water thus held, expressed as a percentage of the total volume of the rock, is called specific retention. The volume of water that is free to drain by gravity from a saturated rock, expressed as a percentage of the total volume of the rock, is called specific yield.

One of the most productive water-bearing materials is coarse, well sorted gravel, in which the spaces between adjacent particles are large and interconnected. A gravel deposit readily absorbs water, stores it in large quantities, and yields it freely to wells. Sand or sandstone deposits generally are more continuous and widespread than gravel deposits, but they compare unfavorably with gravel beds in that they have smaller interstices, which conduct water less readily, and give up a smaller proportion to wells. The poorest water-yielding material is clay. Clay is very soft and plastic when wet and any joints or other openings formed in it are readily closed, even under slight pressure. Clay deposits, however, may yield usable quantities of water to shallow dug wells with large infiltration areas and considerable storage capacity. Several types of openings or interstices and the relation of texture to porosity are shown in figure 53.

SOURCE AND OCCURRENCE

When rain, snow, sleet, and hail fall on the land some of the water flows directly into surface streams, some returns to the atmosphere through evaporation,

1. Names of geologic units referred to in this chapter and on plate 3 are those recommended by the U. S. Geological Survey. However, to maintain uniformity with the style of other chapters in this report, these names are capitalized according to current typographical style of the Ohio Division of Geological Survey.

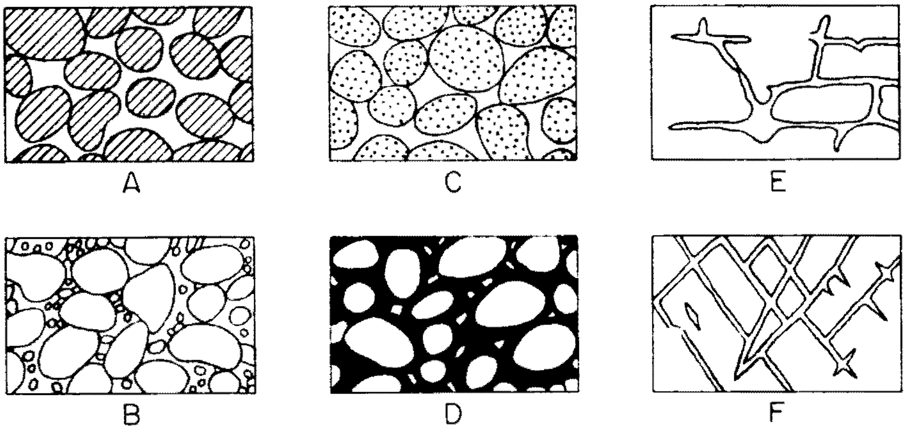


Figure 53. - Diagram showing several types of rock interstices and the relation of rock texture to porosity. A, well sorted sedimentary deposit having a high porosity; B, poorly sorted sedimentary deposit having low porosity; C, well sorted sedimentary deposit consisting of pebbles that are themselves porous so that the deposit as a whole has a very high porosity; D, well sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; E, rock rendered porous by solution; F, rock rendered porous by fracturing. (From O. E. Meinzer, 1923b, p. 3)

and the remainder seeps into the ground. A part of the water that seeps into the ground is held by molecular attraction in the unsaturated zone, called the zone of aeration, and is subsequently transpired by plants. This water is called suspended or vadose water. The remaining water moves downward to the zone of saturation and is called ground water. Only water in the zone of saturation is available to supply wells and springs (fig. 54).

Water in the zone of saturation may be confined or unconfined. Where the upper surface of the zone of saturation is unconfined, the upper limit of this zone is called the water table. When a well is drilled or dug into the zone of saturation, ground water enters the well and rises to the level of the water table. The water table, which conforms in a general way to the shape of the land surface, is not static but fluctuates with daily, seasonal, and yearly variations in precipitation, withdrawal from wells, and other factors.

Where water in the zone of saturation is confined under pressure between relatively impermeable beds, and the water level in a tightly cased well penetrating the zone rises above the bottom of the upper confining bed, the water thus confined is said to occur under artesian conditions. The imaginary surface formed by connecting the heights to which the water level would rise in wells tapping an artesian aquifer is called the pressure or piezometric surface. The term "piezometric surface" may be applied also to the water-table surface; however, the reverse is not true. The occurrence of ground water under artesian and water-table conditions is shown in figure 55.

MOVEMENT

The movement of water in openings in rocks is controlled principally by two forces, gravity and molecular attraction. Gravity causes water to move in response

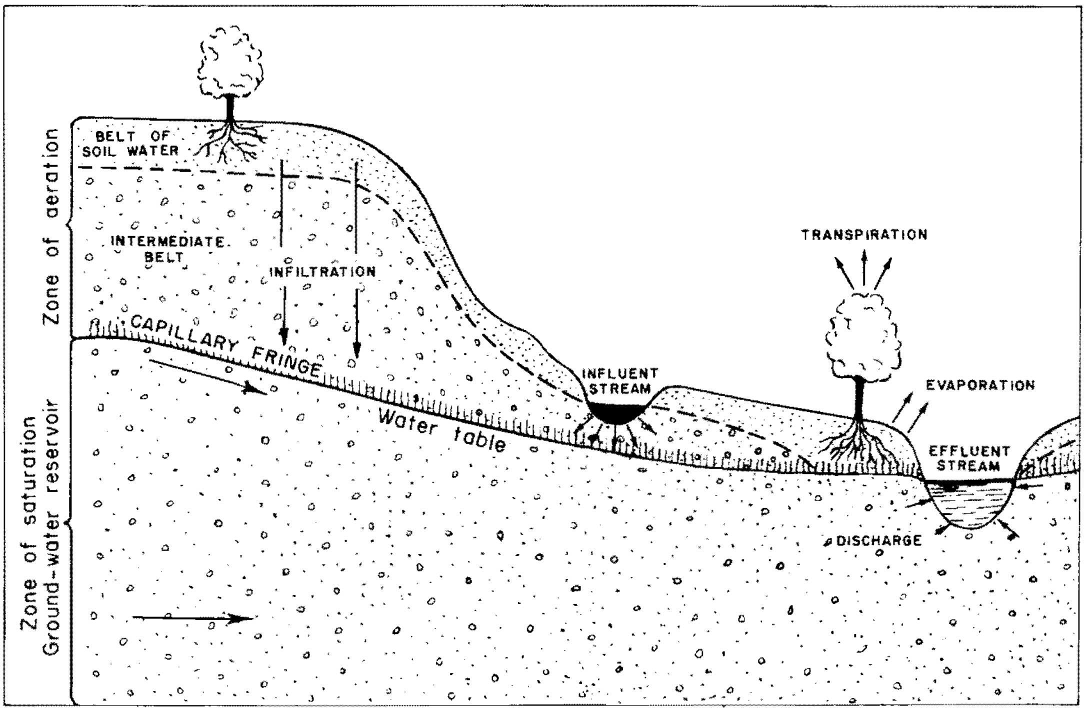


Figure 54. - Diagram showing zones and direction of movement of subsurface water.

to the prevailing hydraulic gradients; that is, it is the force that causes water to flow from springs, or to enter wells, and to issue from flowing wells. The molecular forces, adhesion between molecules of different kinds and cohesion between molecules of the same kind, tend to resist flow. The rate of ground-water movement ranges from a fraction of an inch per year to several feet per day. In rocks having large openings gravity is the major controlling force in the movement of water, and in rocks having small openings molecular attraction is the chief controlling force.

Free or unconfined ground water always moves by gravity from points of higher to points of lower elevation. Artesian or confined water moves from recharge to discharge areas much as water under pressure in a pipe moves to points of withdrawal when it is connected to a reservoir at a higher elevation. The direction of movement between recharge and discharge areas can be determined from contour maps of the piezometric surface.

HYDRAULIC PROPERTIES OF WATER-BEARING MATERIALS

A water-bearing zone that yields water to wells or springs in usable quantities is called an aquifer. In areas where ground water is obtained with difficulty, a zone yielding 1 or 2 gpm (gallons per minute of water) to wells may be classed as an aquifer. However, in other areas where wells may obtain a hundred or more gpm, a zone which yields less than a few gpm might not be classed as an aquifer.

A crude measure of the water-yielding property of an aquifer is the specific capacity of a well tapping the aquifer. The specific capacity generally is expressed in gpm per foot of drawdown, and is determined after a balance is established between recharge and pumping, at which time the pumping level in the well remains

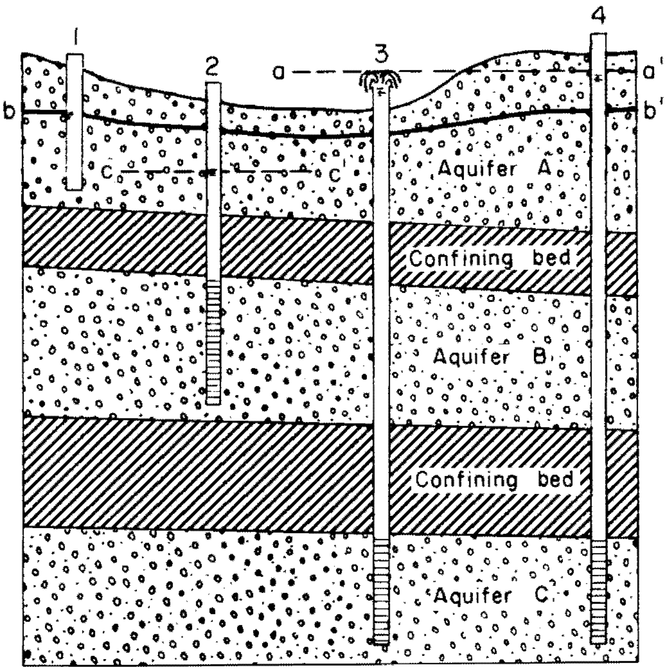


Figure 55. - Sketch showing the occurrence of ground water under water-table and confined conditions. a-a' is the piezometric surface of aquifer C, and wells 3 and 4 are artesian wells. b-b' is the water table, and well 1 is a water-table well. c-c' is the piezometric surface of aquifer B, and well 2 is an artesian well.

approximately stationary. If a well yields 1,000 gpm and has a maximum drawdown of 100 feet, the specific capacity of the well is 1,000 divided by 100, or 10 gpm per foot of drawdown.

Although determining the specific capacity of a well is the oldest and still the most widely used method of evaluating the hydraulic properties of an aquifer, these properties may be expressed more precisely in terms of the coefficients of permeability, transmissibility, and storage. The data required to compute these coefficients are usually obtained by making controlled pumping tests on the aquifer. The coefficients of permeability, transmissibility, and storage are then used in making quantitative estimates of water available in the aquifer, and of future water-level declines that will result from pumping.

The coefficient of permeability is the rate, in gallons per day, at which water at a temperature of 60° F will flow through a cross-sectional area of 1 square foot under a hydraulic gradient of 100 percent (Wenzel, 1942, p. 7). However, because of the nearly constant temperature of the ground water in a given region the coefficient of permeability generally is not corrected for the difference between 60° F and the prevailing temperature of the ground water. This determination under prevailing conditions is called the field coefficient of permeability (Wenzel, 1942, p. 7).

During the past 25 years, new formulas and field methods for appraising the hydraulic properties of an aquifer have been developed. (See Brown, R. H., 1953, and Ferris and others, in press) The increasing use of these new formulas has resulted in the wide adoption of the term "coefficient of transmissibility," which was first introduced by C. V. Theis (1935, p. 520). The coefficient of transmissibility may be defined as the rate of flow of water in gallons per day under a unit hydraulic gradient, through a column of water-bearing material which measures 1 foot in width and extends the full saturated thickness of the aquifer. In this definition, no mention is made of the temperature of the water, so that in practice the coefficient of transmissibility is equal to the average field coefficient of permeability multiplied by the thickness of the aquifer, in feet.

The coefficient of storage of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface (Lang, 1961, p. 7). When the water table in an unconfined aquifer is lowered by pumping, ground water is derived from storage by the gravity drainage of the pore spaces in that portion of the aquifer unwatered by the pumping. A well drilled into an artesian aquifer, unlike one drilled into a water-table aquifer, withdraws water from storage without draining the water-bearing rocks. The water is derived by compaction of the aquifer and its associated beds and by expansion of the water itself while the openings remain full.

FLUCTUATIONS OF WATER LEVELS

The water table or piezometric surface of a ground-water reservoir does not remain stationary, but fluctuates up and down much like the water in a surface reservoir. Because water occupies only part of the volume of a ground-water reservoir the water level fluctuates more by the addition or depletion of a certain quantity of water than does the level of a surface reservoir. For example, if the materials comprising a water-table aquifer have a specific yield of 25 percent, the addition of 1 foot of water to the saturated deposits will raise the water level in those materials about 4 feet. Whether the water level in the ground-water reservoir rises or falls depends upon the amount of recharge to, or discharge from, the reservoir. In general the water table declines during the summer as a result of greater loss of water by evaporation and by transpiration from plants, and it rises during the winter, when these losses are at a minimum. Figure 56 shows an automatic water-stage recorder used to record fluctuations of ground-water levels; figure 57 shows a typical installation of this recording gage on an observation well in Ohio.

An observation-well program was begun in Fairfield County in March 1946 when a recording gage was installed on well F-1[1] in Richland Township. Later, a recording gage was installed on well F-3 in Hocking Township. Well F-1 is drilled into the Logan formation of Mississippian age and the water occurs under artesian conditions. The decline of water level in well F-1 between April 1952 and January 1956 was caused by below-normal precipitation. Well F-3 is drilled into the outwash sand and gravel deposits that immediately underlie the land surface in the Hocking River valley. The water in these deposits occurs under water-table conditions. The rise and fall of the water table in well F-3 is partially obscured by the effect of pumping at the nearby Lancaster municipal well field, about 300 feet distant. Hydrographs of wells F-1 and F-3 are shown in figure 58.

RECHARGE

Recharge is the addition of water to the underground reservoir. The principal sources of recharge are rain or snow falling on the intake area, seepage from

1. Numbering system used by the Ohio Division of Water.

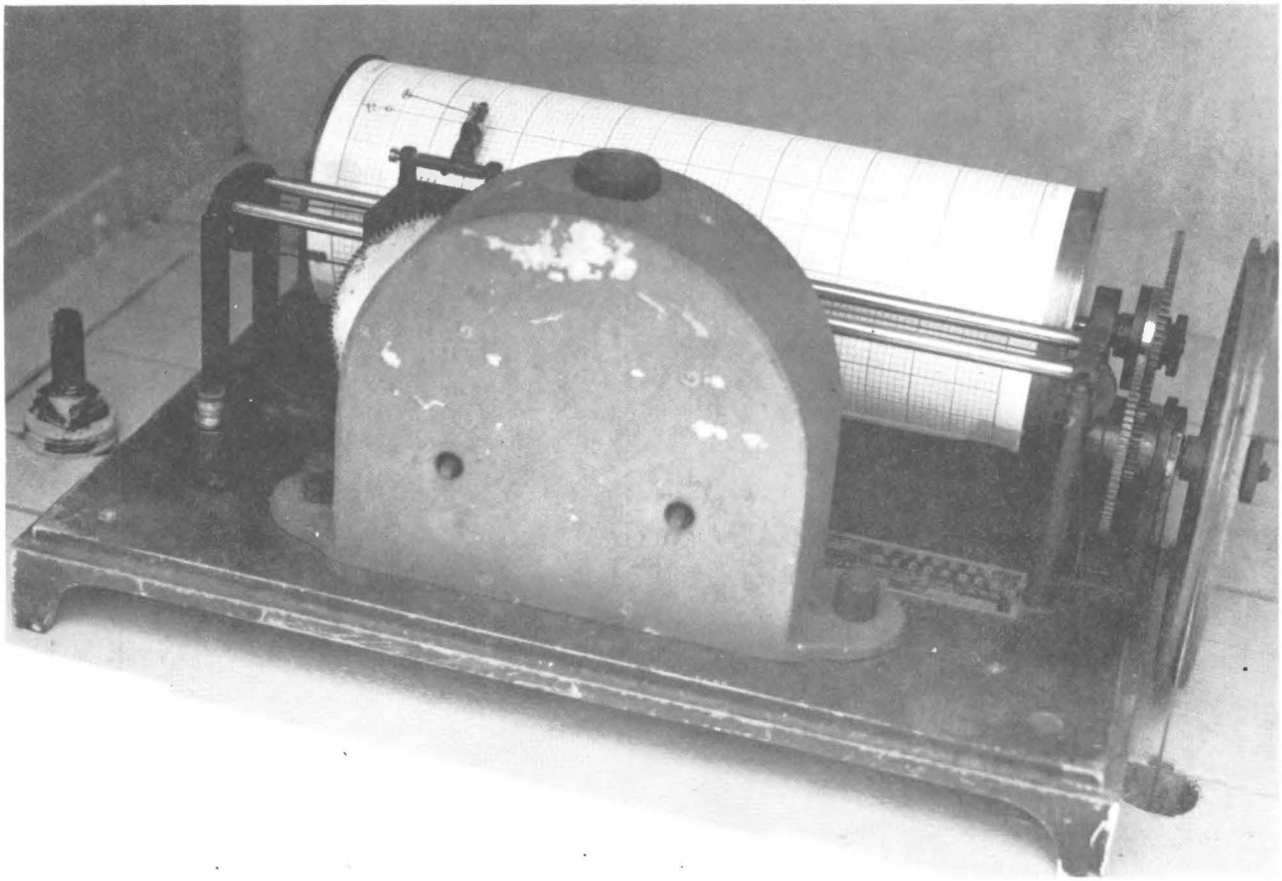


Figure 56. - Photograph of water-stage recorder operating at a well.

streams, subsurface inflow from adjacent areas, and vertical leakage through relatively impermeable beds above or below.

PRECIPITATION

The average annual precipitation in Fairfield County is 40. 5 inches, but only a small part of this amount enters, and thus recharges, the ground-water reservoir. The bulk of the precipitation flows directly to surface streams, evaporates, or is transpired by plants. The amount of water that reaches the zone of saturation depends upon such factors as character of soil and underlying materials, topography, vegetal cover, soil moisture, land use, depth to water, and the air temperature, intensity, duration, and seasonal distribution of precipitation. Figure 59 shows the maximum, minimum, and average monthly precipitation and temperature at Lancaster for the period 1921-50.

SUBSURFACE INFLOW

Besides recharge derived from direct precipitation, subsurface inflow from adjacent areas may contribute to the ground-water supply. A generalized diagram

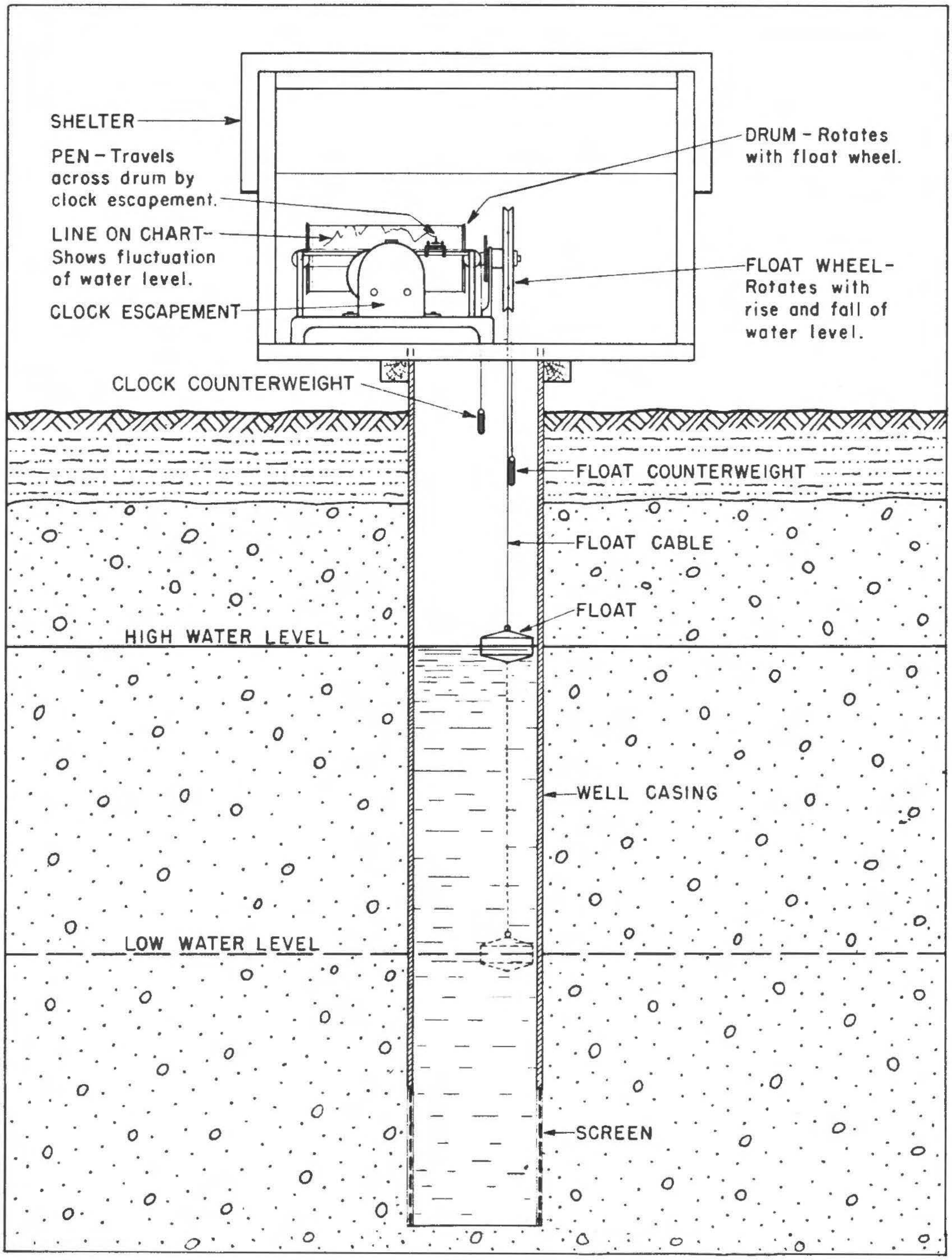


Figure 57. - Diagram of typical installation of water-stage recorder on an observation well.

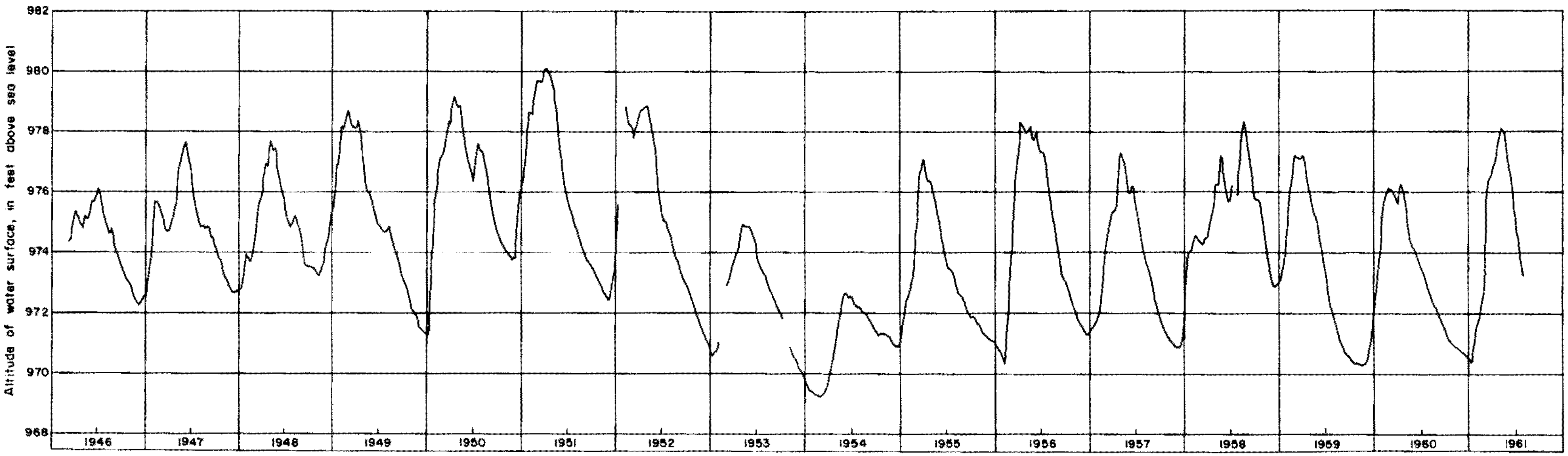
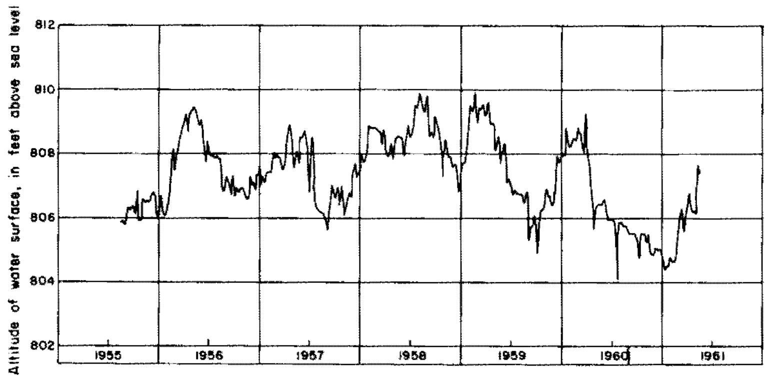


Figure 58. - Hydrographs showing fluctuations of the water levels in wells F-1 (above) and F-3 (right) in Fairfield County, Ohio.



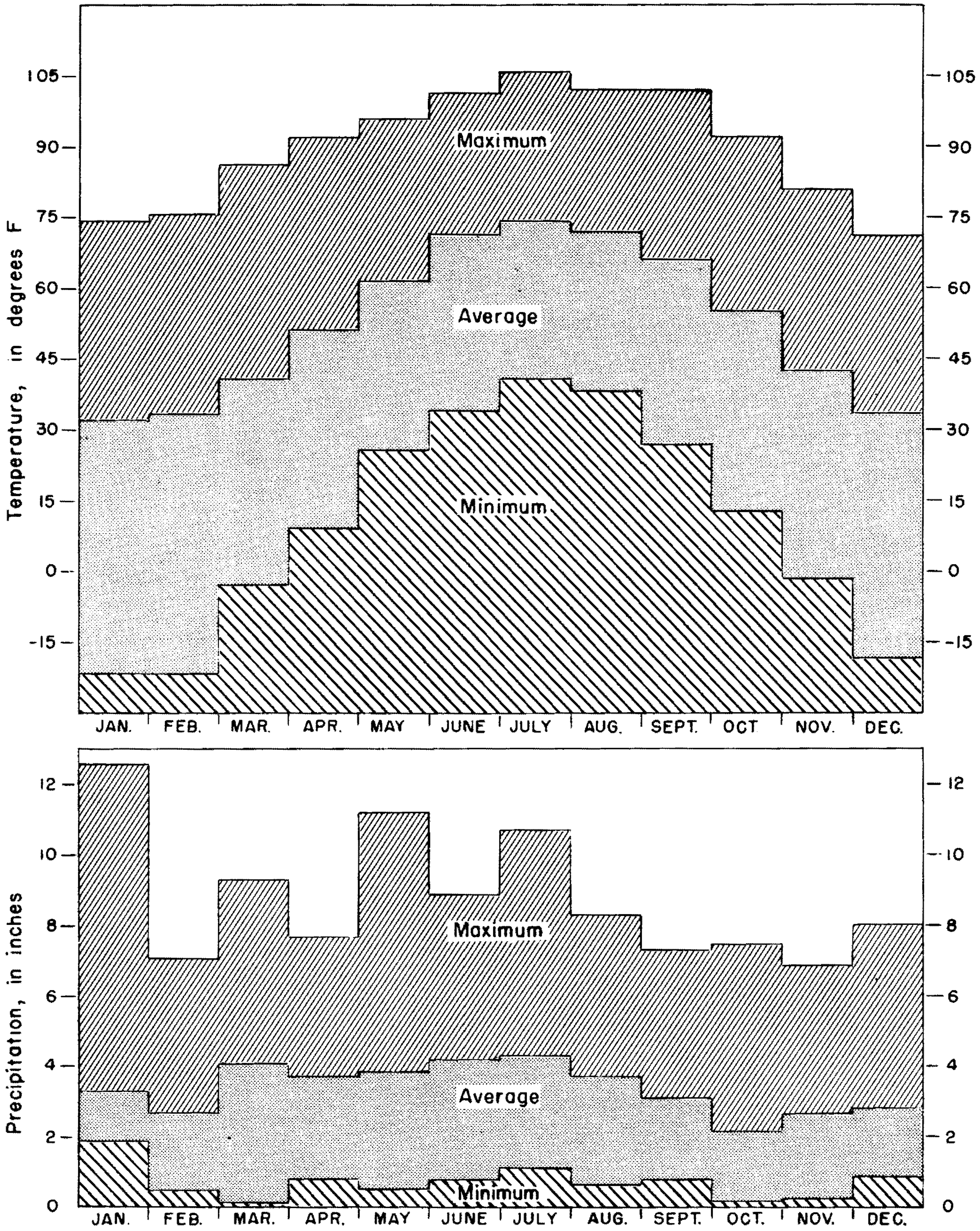


Figure 59. - Diagram showing maximum, minimum, and average monthly precipitation and temperature at Lancaster for the period 1921-50.

illustrating subsurface inflow is shown by figure 60. Here precipitation falls directly on areas A and B and percolates slowly to the zone of saturation. Ground-water pumpage from the well in area B meanwhile has been taking water from storage so that the water level in area B is lower than that in area A. Water, in response to the difference in head between areas A and B, moves through the permeable zone, much as water in a pipe, to replenish the supply taken from area B.

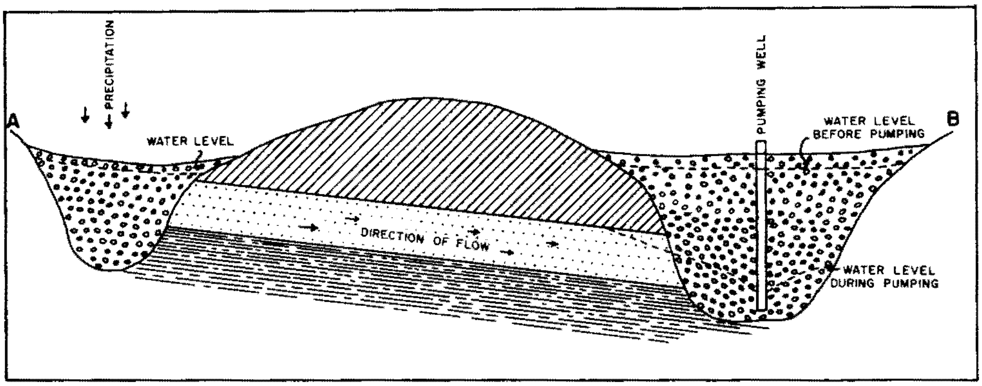


Figure 60. - Generalized diagram showing recharge to unconsolidated deposits by subsurface inflow.

INDUCED INFILTRATION

Another important source of recharge to ground-water reservoirs in Ohio is the induced infiltration of surface water. Recharge to an aquifer by induced infiltration occurs when the water table is below the water surface in a stream or lake, and the stream bed or lake bottom is permeable (fig. 61). An example of recharge by the induced infiltration of surface water occurs in the valley of the Hocking River at Lancaster. Here pumping from the municipal well field has lowered the water table below the water surface in parts of the Hocking River. Water is thereby induced to flow from the river into the ground-water reservoir.

WATER-BEARING PROPERTIES OF GLACIAL AND ALLUVIAL DEPOSITS

TILL

Till deposits of the ground moraines and end moraines, because of their low permeability, yield water very slowly to wells. Shallow dug wells are common in till deposits because such wells offer the advantanges of a large infiltration area, a

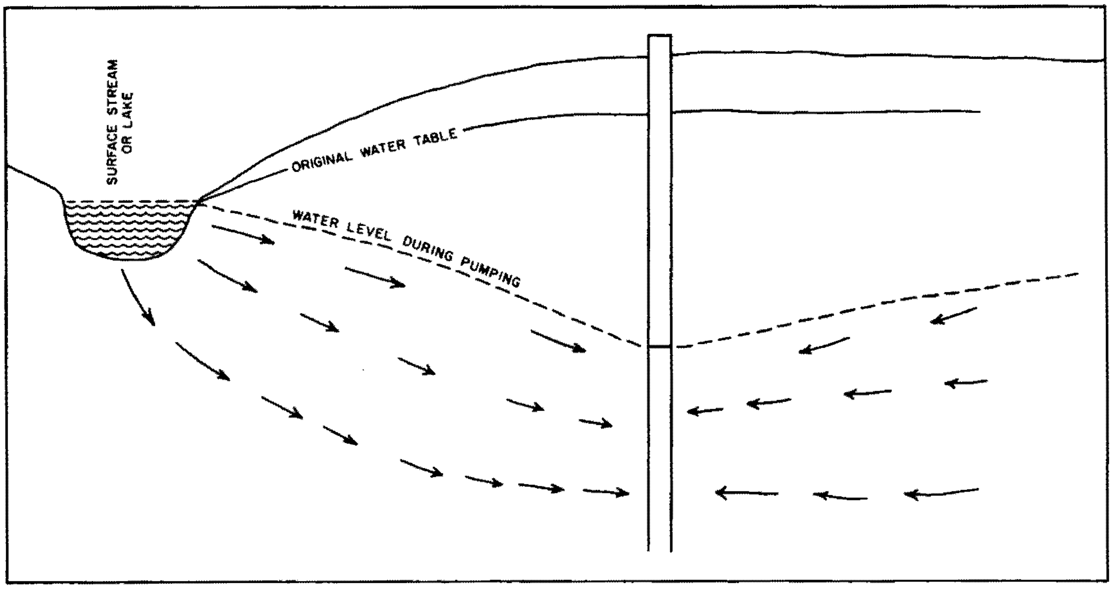


Figure 61. - Generalized diagram showing how water can be induced to flow from a surface-water source to a well.

large storage capacity, and comparatively inexpensive construction. Water yields of shallow dug wells in till deposits are usually adequate for hand pumps but seldom yield enough water to supply powered pumps. Therefore, cisterns commonly are used to supplement dug wells.

Many till deposits 30 feet or more in thickness contain interbedded sand and gravel layers called "gravel streams" or "pockets" by drillers. These sand and gravel deposits probably were laid down by smaller melt-water streams at the bottom of the glaciers and were later covered by till deposited by the overlying ice. Yields from these "gravel streaks" generally are adequate for domestic and stock supplies. Thick and extensive deposits of glacial till underlie large areas in Amanda, Liberty, and Violet Townships. Wells drilled into these deposits average about 90 feet in depth and yield 5 to 10 gpm of water.

SAND AND GRAVEL DEPOSITS

The best aquifers in Fairfield County are the valley-train deposits, (described as outwash terraces on pages 117-121 and 140-143). Changing conditions during their deposition produced variations in character, thickness, and water-bearing properties of these deposits. The thickest and most permeable valley-train deposits are in the Hocking River valley near Lancaster (pl. 2). These outwash sand and gravel deposits are recharged by infiltration from the Hocking River and are capable of yielding large sustained water supplies to wells. Lancaster, for example, pumps $2\frac{1}{2}$ mgd (million gallons per day) from 6 wells drilled in the valley-train deposits just west of the city.

The water-bearing properties of the kame deposits and eskers in Fairfield County are only fair. Although these deposits are coarse textured and permeable they are of small areal extent and lie above the general level of the surrounding terrane. Therefore the water is drained from the kame deposits and eskers rather than stored. Furthermore, because the deposits are at high levels there is less possibility of infiltration from nearby streams.

LACUSTRINE DEPOSITS AND RECENT RIVER ALLUVIUM

The most extensive lacustrine deposits in Fairfield County occur in Berne, Rush Creek, and Walnut Townships. These deposits are made up of layers of clay, silt, and fine sand deposited in ponds, or lakes formed near the front of the glacial ice. The clay or silt is relatively impermeable and yields very little ground water. The sand is fine grained and because of its "runny" characteristics is called quicksand by drillers. The sandy deposits contain large quantities of water but it is difficult to recover because screens fine enough to hold back the sand are too fine to permit rapid entry of water into the well.

Recent alluvium consists mostly of silt and fine sand deposited by the present streams during times when they have overflowed their channels. The alluvium generally is thin, has low permeability, and is not an important source of water.

Most wells in Fairfield County are drilled through the lacustrine and alluvial deposits and obtain water from the underlying deposits and formations. The water in these underlying aquifers occurs under artesian conditions. Wells drilled through the alluvium in the Hocking River valley obtain water from the underlying valley-train deposits. Wells drilled through the lacustrine deposits in Walnut Township and those drilled through the alluvium along Walnut Creek obtain water from deeply buried sand and gravel which was deposited during earlier stages of glaciation.

WATER-BEARING PROPERTIES OF THE CONSOLIDATED ROCKS

Consolidated rocks of sedimentary origin, belonging mostly to the Mississippian system, are exposed extensively in eastern and southeastern Fairfield County. These rocks consist primarily of conglomerate, sandstone, siltstone, and shale. A few thin limestone beds and some coal and clay beds of Pennsylvanian age occur in Richland and Rush Creek Townships.

Most of the water contained in the consolidated rocks occurs along the cracks and bedding planes. Yields from wells drilled into the conglomerate, sandstone, or siltstone beds are much less than from wells in the glacial outwash, but generally they exceed the yields available from the glacial till. Except in a few areas, notably Rush Creek and Berne Townships, the quantities of water available from the consolidated rocks are adequate for most farm and domestic needs. In places, sufficient supplies of water are available from the consolidated rocks to meet small municipal or industrial requirements (pl. 3).

The principal consolidated-rock aquifers in Fairfield County are the Berea, Cuyahoga, and Logan formations of Mississippian age. Most of the water in the consolidated deposits in Fairfield County occurs under artesian pressure. The Cuyahoga formation is the most productive of these formations, yielding 10 to 125 gpm of water to individual wells. The municipal water supplies at Lithopolis and Pickerington are obtained from wells drilled into the Cuyahoga formation. The city wells at Lithopolis are 164 and 165 feet deep and were reportedly pumped at 125 gpm. The municipal well at Pickerington is 102 feet deep and reportedly yields 65 gpm.

In the western part of Fairfield County--Amanda, Bloom, and Violet Townships--a few wells obtain water from the Bedford and Sunbury shales. Yields of water from wells drilled into the Bedford and Sunbury shales, however, are very small, and in most instances the formations are completely unproductive. The Ohio shale of Devonian age, which conformably underlies the Bedford shale, is not a source of water in Fairfield County. All the wells drilled into the Ohio shale were reportedly dry.

No wells inventoried in Fairfield County obtain water from rocks of Pennsylvanian age. The Pennsylvanian sandstone beds are permeable and open to recharge but are generally thin and lie well above drainage. In places the sandstone beds are missing from the section and wells are drilled into the underlying Mississippian rocks to obtain sufficient water for domestic use.

GENERAL GROUND-WATER CONDITONS

The ground-water sources in Fairfield County are not uniform in yield or depth, due principally to differences in geology and bedrock topography. A map of Fairfield County showing ground-water conditions (pl. 3) was compiled from plates 1 and 2 and from well data in table 8. The well logs shown in figure 62 were also used in compilation of the ground-water map. The water wells for which data are listed have been numbered consecutively by township, beginning with 1 in each township.

The best ground-water areas of the county, designated as "excellent" on plate 3, are along the Hocking River near Lancaster. Here the valley-train deposits yield 500 gpm, or more, of water to wells. Where ground-water levels in the outwash deposits have been sufficiently lowered by pumping, water from the Hocking River infiltrates through the permeable deposits to wells, and large yields are sustained. This occurs at the municipal well field at Lancaster, and the sand and gravel deposits in the Hocking River valley act as natural filter beds.

The next best ground-water areas in Fairfield County, designated as "good" on plate 3, are also underlain by permeable sand and gravel in the form of valley-train deposits. These areas also are in the Hocking River valley, but generally are not traversed by major streams and consequently provide no opportunities for induced stream infiltration. In areas where the "good" valley-train deposits are traversed by streams, as in Berne Township, they are thinner, less permeable, and less extensive than those in the excellent ground-water areas.

In the ground-water areas designated as "good to fair" on plate 3, notably in Walnut Township, thick deposits of glacial drift fill deeply buried valleys in some of which the bedrock floors are more than 300 feet below the general land surface (pl. 1). The surface of these valleys is covered by fairly impermeable deposits of glacial till, lake silts, and Recent river alluvium (pl. 2). Beneath these impermeable deposits are alternating layers of sand, gravel, and clay which yield adequate supplies of water for small industrial and municipal uses.

Good to fair ground-water areas also include areas underlain by the consolidated rocks near Lithopolis and Pickerington. Here, wells for municipal use are drilled into the Cuyahoga formation and yield up to 125 gpm.

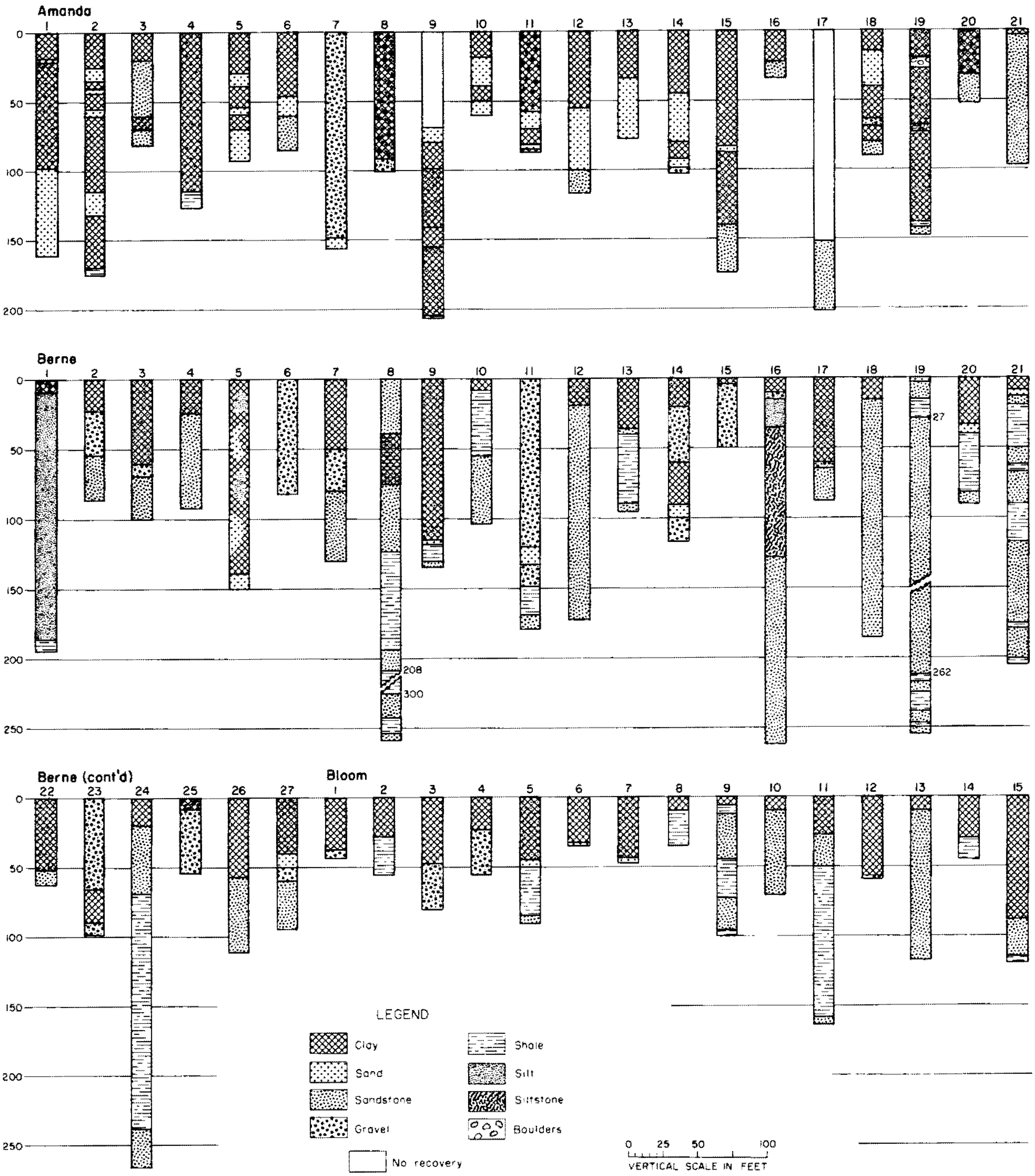


Figure 62. - Logs of wells in Fairfield County, Ohio. Numbers refer to locations shown on plate 3.

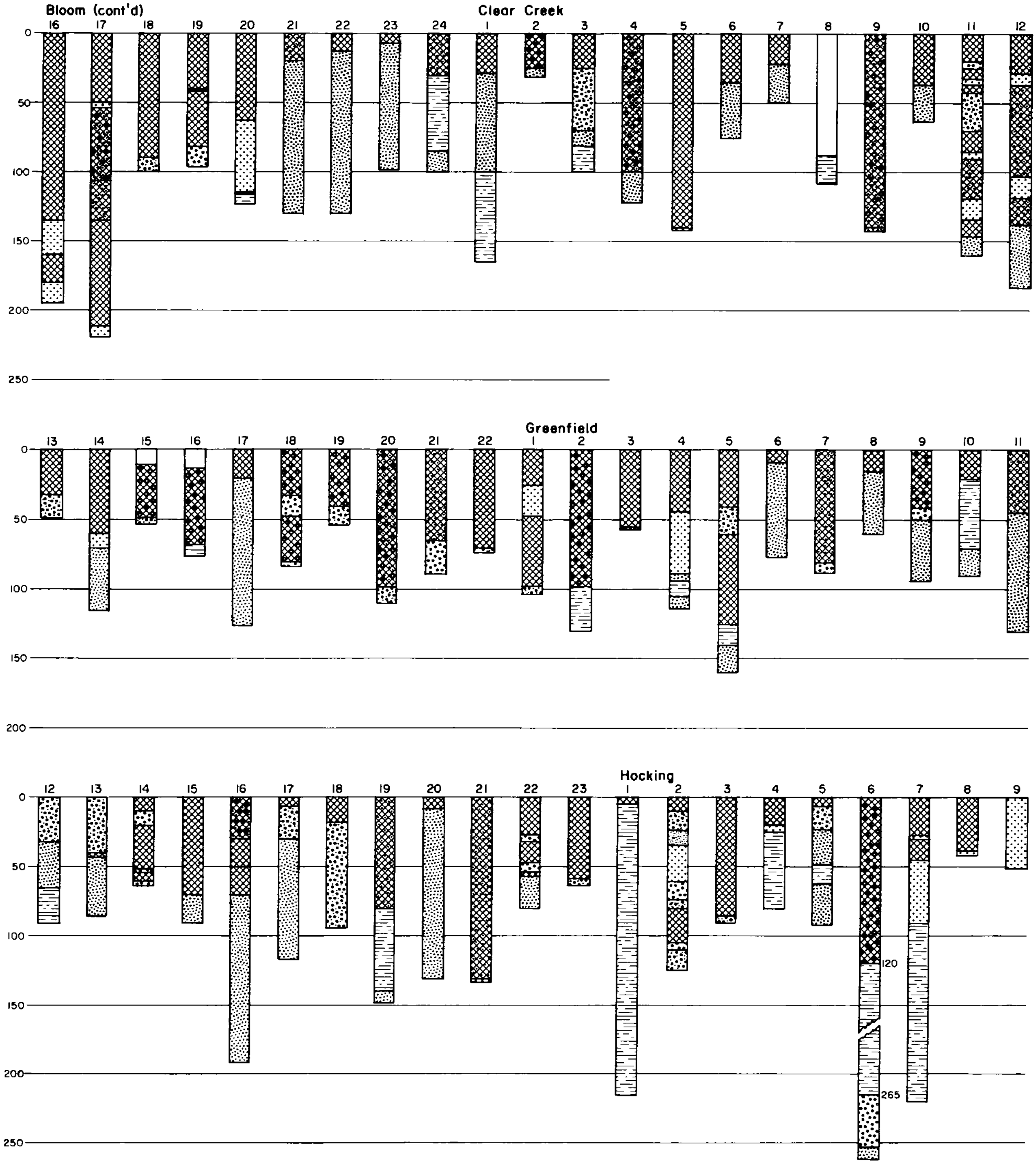


Figure 62. - Logs of wells in Fairfield County, continued.

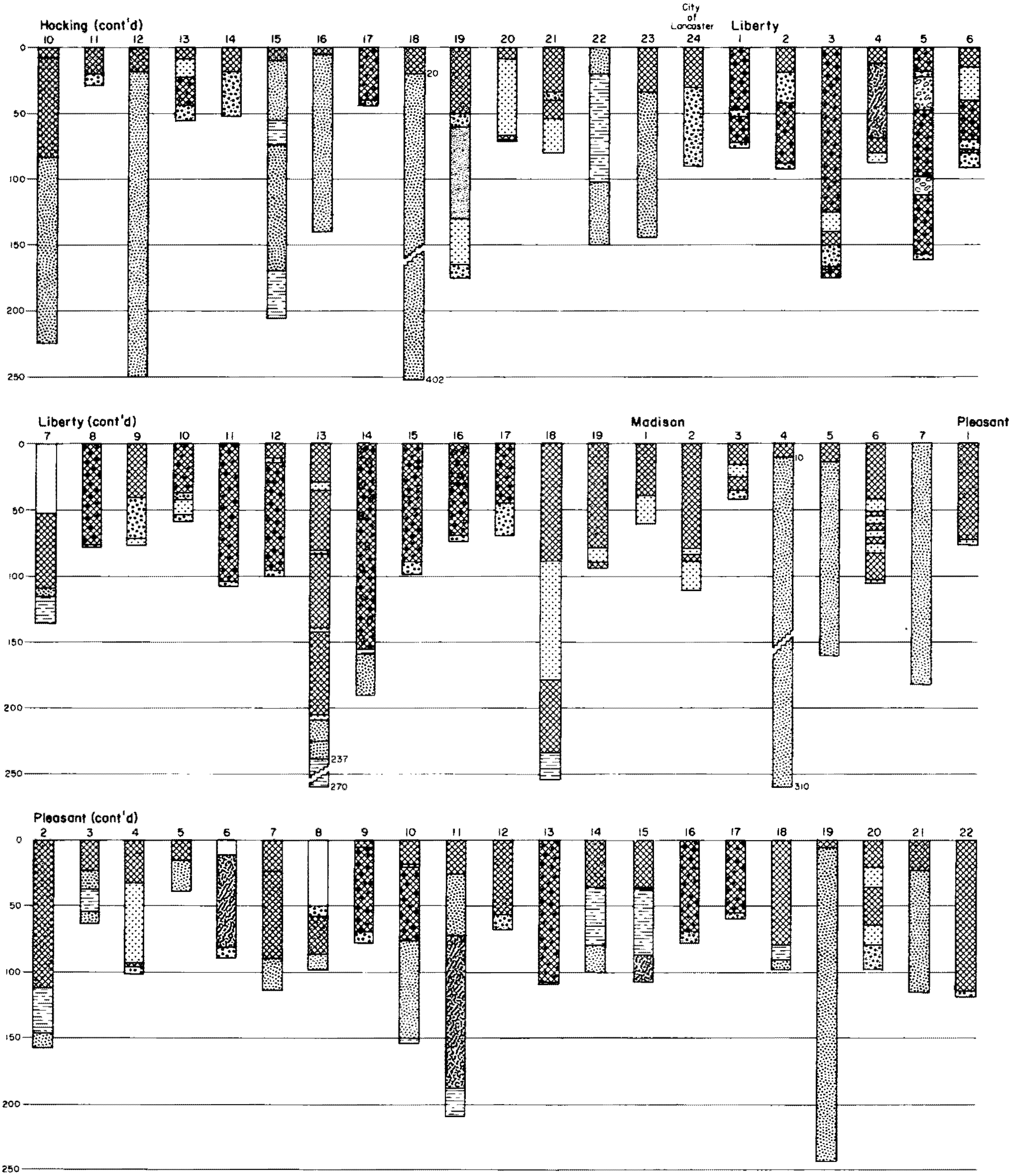


Figure 62. - Logs of wells in Fairfield County, continued.

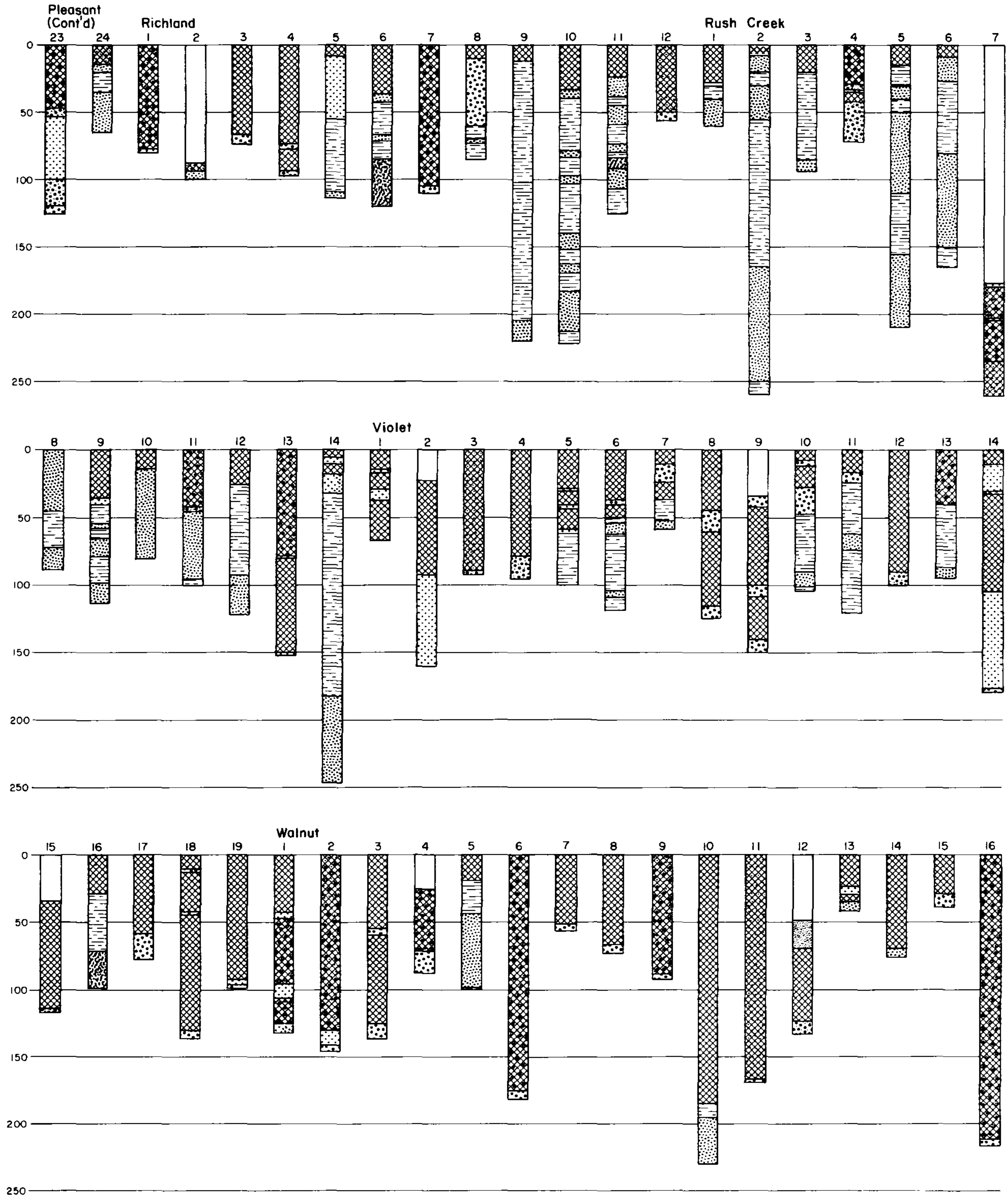


Figure 62. - Logs of wells in Fairfield County, continued.

In the areas designated as "fair" on plate 3, ground-water supplies are obtained from thick deposits of glacial drift and from the consolidated rocks. Ground-water supplies from the glacial drift are generally obtained from interbedded sand and gravel layers within the till of the thick ground moraines or end moraines such as occur in Greenfield, Liberty, Richland, and Violet Townships. Ground-water supplies from the consolidated rocks are generally obtained from the Cuyahoga and Logan formations of Mississippian age. These consolidated formations occur beneath the glacial drift throughout most of the county.

Areas designated as "poor" on plate 3 occur in southeastern Fairfield County, notably in Berne and Rush Creek Townships. The shale deposits of the Pottsville formation[1], which occur at the surface in many places in these areas, are poor sources of water, and few wells yield more than 2 gpm. Wells in the Logan formation, which underlies the Pottsville formation in southeastern Fairfield County, however, yield ample water for household or stock use.

CHEMICAL QUALITY OF THE GROUND WATER

Water samples were collected from five wells in Fairfield County. The wells range from 48 to 246 feet in depth, and their locations are shown in table 8 (Remarks column) and on plate 3. Four of the sampled wells tap unconsolidated glacial materials, and one taps the consolidated rocks of Mississippian age. Analyses of water from the wells were made by the Quality of Water Branch, U. S. Geological Survey, and are shown in table 6. The source and significance of the dissolved solids are reported in ppm (parts per million) and are shown in table 7. Parts per million is a measure of the concentration of a constituent by weight in a million parts of the water by weight.

The iron content and hardness of natural waters affect the suitability of the water for many uses. Iron and manganese were present in all the samples in amounts greater than the limit recommended in the Federal drinking-water standards (U. S. Public Health Service, 1961). Iron was present in concentrations ranging from 0. 63 to 6. 2 ppm, and manganese was present in amounts up to 0. 46 ppm. All the water sampled was excessively hard, and for most purposes softening would be desirable. The hardness of the water ranged from 255 to 344 ppm. The sample with the least amount of dissolved solids, and also the softest water, was taken from well 28, drilled in the valley-train deposits in Berne Township.

The pH of the samples ranged from 6. 9 to 7. 3. The sample with a pH of 6. 9 was taken from the consolidated rocks of the Logan formation in Rush Creek Township. (See table 7 on page 169 for explanation of pH.)

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1. U. S. Geological Survey usage. Current stratigraphic policy of the Ohio Division of Geological Survey is to call the Pottsville a group and to call subdivisions within it cyclothems.

Table 6. - CHEMICAL ANALYSES OF GROUND WATER IN FAIRFIELD COUNTY, OHIO
(Chemical analyses, in parts per million)

Township and well no.	Owner	Date	Silica (SiO_2)	Iron (Fe)	Man-ga-nese (Mn)	Cal-cium (Ca)	Ni-trate (NO_3)
Berne, No. 28	C. R. Montgomery	9-27-60	12	2.1	.10	71	0.2
Berne, No. 29	Deeds Brothers Dairy	9-27-60	14	.63	.09	89	13.
Rush Creek, No. 14	Walter Wiesman	9-27-60	12	6.2	.46	82	.2
Violet, No. 15	Mrs. Alspaugh	9-27-60	16	1.3	.11	87	.5
Violet, No. 20	Delmer West	9-27-60	17	2.1	.12	72	2.2

Township and well no.	Mag-nesium (Mg)	Stron-tium (Sr)	So-dium (Na)	Po-tas-sium (K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)
Berne, No. 28	19	.2	3.5	1.2	284	27	7.0	.2
Berne, No. 29	27	.1	6.0	1.1	310	37	24.	.1
Rush Creek, No. 14	28	.4	12.	1.9	338	68	3.0	.1
Violet, No. 15	26	10.	26.	1.8	388	58	8.0	1.4
Violet, No. 20	32	3.1	24.	3.8	404	36	3.0	.8

Township and well no.	Dissolved solids (residue as evap-oration at 180° C)	Hardness as $CaCO_3$		Specific conduct-ance (micromhos at 25° C)	pH	Temp. (°F)	Color
		Calcium mag-nesium	Non-carbon-ate				
Berne, No. 28	246	255	22	485	7.0	62	1
Berne, No. 29	332	333	79	629	7.0	59	2
Rush Creek, No. 14	338	320	43	621	6.9	56	1
Violet, No. 15	397	336	18	695	7.1	64	2
Violet, No. 20	344	315	0	654	7.3	55	1

Table 7. - SOURCE AND SIGNIFICANCE OF DISSOLVED MINERAL CONSTITUENTS AND PROPERTIES OF WATER

Constituent or property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, usually in small amounts from 1-30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of soluble iron in surface waters usually indicate acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. Federal drinking water standards state that iron and manganese together should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Manganese (Mn)	Dissolved from some rocks and soils. Not so common as iron. Large quantities often associated with high iron content and with acid waters.	Same objectionable features as iron. Causes dark brown or black stain. Federal drinking water standards provide that iron and manganese together should not exceed 0.3 ppm.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (See hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Strontium (Sr)	Dissolved from rocks and soils. Found in sea water and many brines. Present in waters of local areas where strontium minerals such as celestite and strontianite are present.	Naturally occurring strontium is similar chemically to calcium and only adds to the hardness of water. Radioactive isotopes of strontium, as from nuclear bomb fallout, can be harmful. These isotopes can be detected by radiometric measurements and <u>are not</u> reported here as strontium (Sr).
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon-dioxide gas. In combination with calcium and magnesium cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. Federal drinking water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium gives salty taste to drinking water. In large quantities increases the corrosiveness of water. Federal drinking water standards recommend that the chloride content should not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Enters many waters from fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual. (Maier, F. J., 1950, Fluoridation of public water supplies, Jour. Am. Water Works Assoc., vol. 42, part 1, p. 1120-1132.)
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentrations much greater than the local average may suggest pollution. There is evidence that more than about 45 ppm of nitrate (NO_3) may cause a type of methemoglobinemia in infants, sometimes fatal. Water of high nitrate content should not be used in baby feeding (Maxcy, K. F., 1950, Nat. Research Council, Bull. San. Eng., p. 265, App. D.) Nitrate has shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes some water of crystallization.	Federal drinking water standards recommend that the dissolved solids should not exceed 500 ppm, however 1,000 ppm is permitted under certain circumstances. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All of the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness up to 60 ppm are considered soft; 61 to 120 ppm, moderately hard; 121 to 200 ppm, hard; more than 200 ppm, very hard.
Specific conductance (micromhos at 25° C)	Mineral content of the water.	Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents. Varies with temperature; reported at 25° C.
Hydrogen ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.
Temperature		Affects usefulness of water for many purposes. For most uses, a water of uniformly low temperature is desired. Shallow wells show some seasonal fluctuations in water temperature. Ground waters from moderate depths usually are nearly constant in temperature, which is near the mean annual air temperature of the area. In very deep wells, the water temperature generally increases on the average about 1° F with each 60-foot increment of depth. Seasonal fluctuations in temperatures of surface waters are comparatively large depending on the depth of water, but do not reach the extremes of air temperature.
Color	Yellow-to-brown color of some waters is usually caused by organic matter extracted from leaves, roots, and other organic substances. Objectionable color in water also results from industrial wastes and sewage.	Water for domestic and some industrial uses should be free from perceptible color. Color in water is objectionable in food and beverage processing and many manufacturing processes.

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS IN FAIRFIELD COUNTY, OHIO

Well number: The number of the well shown on the well location map, plate 3 and above the graphic illustration of the well log in figure 62.

Owner or name: Name of land owner or tenant at the time the well was drilled or at the time of the well inventory.

Elevation at well: Determined approximately from the topographic maps of the U. S. Geological Survey.

Depth to bedrock: Depth to the top of the consolidated rocks.

Depth of well: Depth reported by driller, owner, or tenant.

Principal water-bearing bed: Character of material - Type of material from which water was obtained or in which the well was terminated: ss, sandstone; sh, shale; sd, sand; gr, gravel; cl, clay or till. Geologic unit - Doh, Ohio shale (Devonian age); Mbe, Bedford shale (Mississippian age); Mb, Berea sandstone (Mississippian age); Ms, Sunbury shale (Mississippian age); Mc, Cuyahoga formation (Mississippian age); Ml, Logan formation (Mississippian age); Pp, Pottsville formation (Pennsylvanian age); Gla, Glacial drift.

Water level: Below land surface - Depth to water in the well as reported by the driller, owner, or tenant. Date - Date of measurement of the static water level, yield, or drawdown, or the date the well was completed.

Yield: Rate - Rate at which well was pumped or bailed. Drawdown - Amount of lowering of the water level in the well caused by pumping the well at the rate shown in the yield column.

Diameter of well: Approximate inside diameter of casing.

Use: I, industrial; D, domestic; S, stock; PS, public supply.

Remarks: A, chemical analysis of water from the well is shown in table 6; State observation wells are shown with letter and number (e.g. F-2). All wells are drilled and logs are on file at the Ohio Department of Natural Resources, Division of Water.

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic unit	Water level: Below land surface (feet)	Water level: Date	Yield: Rate (g.p.m.)	Yield: Drawdown (feet)	Diameter of well (inches)	Use	Remarks
	Amanda Township												
1	Ralph Allen	1020		162	sd	Gla	60	7-19-54			4	D	
2	Robert Barr	905	170	175	sh	Mbe		9- 1-55					Dry hole.
3	Amanda Twp. Cemetery	935	20	82	ss	Mc		11- 3-52			4	PS	
4	M. E. Griffith	935	115	127	sh	Ms	40	1-23-58	14	70	4	D	
5	Hugh Huffer	955		93	sd	Gla		9- 1-53			4	D	
6	Don Hinton	920	60	85	ss	Mc	25	9-25-47			4	D	
7	Joe Haines	890		156	sd	Gla	60	4-27-56			4	D	
8	Merle Kinser	920		101	sd	Gla		3-16-53			4	D	
9	Raymond Mertz	930	207	207	sh	Doh		3-27-52			4	D	Dry hole.
10	Joe Solt	925		60	sd	Gla		1-28-53			4	D	
11	Bill Deffenbaugh	935		87	sd	Gla	30	1-13-58	5		4	D	
12	Fred Bates	1110	100	117	ss	Mc	50	10- -55	18	15	4	D	
13	Herbert Ruff	935		77	sd	Gla					4	D	
14	Irvin Thomas	910		103	gr	Gla	45	1-20-52	2	8	4	D	
15	Ray McKenzie	980	140	174	ss	Mc	20	8- 1-58	10	30	4	D	
16	James Pontius	955	22	33	sh	Mc	18	12- 3-58	10	2	4	D	
17	Clay Sandfried	1130	56	202	ss	Mc	70	4-30-58	5		4	D	
18	Barney Ragen	945	80	90	ss	Mc	10	7-10-56	15	1	4	D	
19	George & Lucille Smith	930	139	149	ss	Mb	28	2-15-59	5	140	5	D	
20	Ernest Thomas	970	31	52	ss	Mc	16	3-21-59	40	20	5	D	
21	William Skaggs	1050	3	97	ss	Mc	55	6- 9-55	4		4	D	

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS, continued

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic unit	Water level: Below land surface (feet)	Water level: Date	Yield: Rate (g.p.m.)	Yield: Drawdown (feet)	Diameter of well (inches)	Use	Remarks
						Berne Township							
1	R. W. Pedigo	830	185	194	sh	Mc		12-21-54	5		5	D	
2	Fred Murphy	830	54	86	ss	Mc	22	11-16-55	20	1	5	D	
3	George Sello	830	69	100	ss	Mc		11-16-53			4	D	
4	H. Berry	850	24	92	ss	Mc		10- 6-54			4	D	
5	Charles Dishon	830		150	sd	Gla		8-12-54	8		4	D	
6	F. H. Brewer Co.	790		82	sd & gr	Gla		3- -55			4		
7	Joe Marcinko	840	80	130	ss	Mc		5-25-54					
8	Clarence Keller	800	25	334	ss	Mc	219	10-25-57	10	269	5	D	A
9	Leo Flowers	880	117	134	ss	Mc		4-12-55	5		5	D	
10	St.Paul Lutheran Church	910	14	103	ss	Mc	50	5- 2-56	20	12	5	D	
11	Crawfish Grange 2190	850	149	178	ss	Mc	68	3-13-57	9	34	5	D	
12	Walter Azbell	1030	19	172	ss	Mc		8-18-53			4	D	
13	Paul Snyder	830	40	95	ss	Mc	40	8-14-53	10	8	4	D	
14	Harrold Glenn	790		116	gr	Gla		2-26-53			4	D	
15	William Fisher	790		50	sd & gr	Gla	13	8-30-56	10		5	D	
16	C. E. Hart	790	35	262	sh	Mc	60	7- -55			5	D	
17	Edward Danbenmire	810	64	87	ss	Mc	1	12-18-55	20	20	5	D	
18	John Cunningham	1160	15	185	ss	Mc		4-25-53			5	D	
19	Robert Heath	1102	2	305	ss	Mc	240	8- 3-57	5	288	5	D	
20	Rex Hartman	932	33	90	ss	Mc	70	11-11-54	2	30	4	D	
21	Emanuel Kilbarger	900	12	205	sh	Mc	175	11- 1-56	4	203	5	D	
22	Charles Wilson	810	51	61	ss	Mc	6	9- 4-58	15	25	4	D	
23	Harold Clark	850		99	sd & gr	Gla	45	2-23-59	12	25	4	D	
24	Paul Farrow	910	20	256	ss	Mc	128	4-30-59	20	40	5	D	
25	Ralph Ackers	790		53	sd & gr	Gla	19	8-14-59	14	39	4	D	
26	F. J. Damner	840	56	111	ss	Mc	90	6-26-58	20		5	D	
27	Clarence Killbarger	815	54	94	ss	Mc		6-12-54			4	D	
28	C. R. Montgomery	790		57	sd & gr	Gla	23	9-18-58	15	47	5	D	A
29	Deeds Dairy	800		105	gr	Gla	18	7- 8-54			4	DS	A
						Bloom Township							
1	Lawrence Dill	810		44	gr	Gla	26	6-14-54	10	3	6	D	
2	Bruce Taylor	835	28	55	sh	Mbc		9-17-53			10		Dry hole.
3	Raymond Moore	830		80	sd & gr	Gla	15	8-21-56	8	6	4	D	
4	Bros Stebelton	850	23	55	ss	Mc	26	8-12-55	8	5	4	D	
5	Lundy Woolsey	900	45	90	ss	Mc	20	7- 3-54	10	6	4	D	
6	Howard Stombaugh	810		35	sd	Gla	20	2-19-57	15	6	4	D	
7	D. W. Bell	800		47	sd	Gla		9-25-53			4	D	
8	L. A. Howe	790	10	35	sh	Mbe		2- 6-57					Dry hole.
9	R. T. Ridgeway	865	6	100	sh	Doh	67	9-21-53	10	12	5	D	

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS, continued

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic unit	Water level: Below land surface (feet)	Water level: Date	Yield: Rate (g.p.m.)	Yield: Drawdown (feet)	Diameter of well (inches)	Use	Remarks
	Bloom Township												
10	Wallace Daniel	925	10	70	sh	Ms	20	8-26-52	5		6	D	
11	Village of Lithopolis	980	27	164	ss	Mc	9	5-18-57	70	39	10	D	
12	Carl Zangmeister	990		58	gr	Gla	22	8-15-52	5	3	4	D	
13	Paul Alexander	1070	10	117	ss	Mc	85	2-13-57	10		5	D	
14	H. F. Fisher	880	30	45	sh	Ms	25	5-18-54	3		6	D	
15	Fred Donley	990	87	120	sh	Ms	55	5- 5-56	6	55	4	D	
16	C. F. Nieswander	990		195	sd	Gla		11-20-53			4	D	
17	Francis Pheaster	990		220	sd	Gla	100	3-26-56			4	D	
18	John Sitterly	1020		100	sd & gr	Gla		1-28-52			4	D	
19	Emil Coontz	1030		96	gr	Gla	62	9- 3-53	6	5	4	D	
20	Presbyterian Church	1050	116	123	ss	Mc	42	10- 9-57	8	8	4	D	
21	Zaayer	1030	20	130	ss	Mc	108	10- 6-56	10	5	4	D	
22	Charles Roisier	1080	12	130	ss	Mc	45	5- 5-55	10	106	5	D	
23	Fred Ward	1080	6	98	ss	Mc	68	9-18-57	8	6	4	D	
24	A. C. Conrad	890	30	100	ss	Mc		7-29-57			4	D	
	Clear Creek Township												
1	Harold Reincheld	1110	28	165	sh	Mc	100	10-11-54			4	D	
2	Virgil Wright	1090	25	31	ss	Mc	20	9-10-57	14	11	4	D	
3	Lewis Young	910	70	100	ss	Mc		1-27-54			4	D	
4	Milt Dover	1010	100	122	ss	Mc	60	9-16-57	7	2	4	D	
5	Carl Valentine	980		142	sd	Gla		5-18-56	9	1	4	D	
6	Randolph Wolf	940	35	75	ss	Mc	12	11- -51	30	10	4	D	
7	Wayne Ardge	890	21	50	ss	Mc	10	3- -53	18	10	4	D	
8	Stewart Dennis	1070		108	sh	Mc		6- 2-51				D	Old well deepened from 88 ft.
9	Addison Knecht	1130		143	sd & gr	Gla		2-26-53			5	D	
10	Phillip Davis	1030	37	63	ss	Mc	30		10	10	4	D	
11	Sam Meister	890	143	160	ss	Mb	22	5-10-58	15	12	4	D	
12	Loren Armstrong	930	138	184	ss	Mc	60	5-10-58			4	D	
13	Sam Davis	935		49	gr	Gla	18	11- -53	18	3	4	D	
14	Leslie Lutz	925	60	115	ss	Mc	55	12- 8-54	6		4	D	
15	Lloyd Ratcliffe	1050		53	sd & gr	Gla	27	6-19-58	15	10	4	D	
16	Merle Ratcliffe	950	67	76	ss	Mc	37	6-14-58	10	10	4	D	
17	Roy Wilson	1040	20	126	ss	Mc	59	3-28-59	9		5	D	Well pumped dry in 2 hrs.
18	Walter Hartley	960		83	gr	Gla	22	2- 2-59	15	5	4	D	
19	Ross Strickler	880		55	sd & gr	Gla		6-23-52			4	D	
20	Arthur Cove	990		110	sd & gr	Gla	87	6- 6-58	12	3	4	D	
21	Thomas	1105		89	gr	Gla	18		9	50	4	D	
22	Dick Peters	980		73	gr	Gla	30	11-10-58	9	5	4	D	

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS, continued

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic unit	Water level: Below land surface (feet)	Water level: Date	Yield: Rate (g.p.m.)	Yield: Drawdown (feet)	Diameter of well (inches)	Use	Remarks
						Greenfield Township							
1	David Thompson	960		103	sd & gr	Gla	38	12-15-55	20	1	5	D	
2	Roger Davis	970	98	130	sh	Mc	15	8-29-57	2	112	4	D	
3	Anthony Uhl	840		57	sd & gr	Gla	32	12-22-55	12	10	4	D	
4	Leo Hilbarger	980	88	114	ss	Mc	60	7-22-55	7	12	5	D	
5	Harry Poling	1000	125	160	ss	Mc	70	4-26-55	6	5	4	D	
6	Theodosia Kiger	920	9	76	ss	Mc	50	10-15-56	5	3	4	D	
7	Warren Calvert	850		87	gr	Gla	60	4- 4-58	7	1	5	D	
8	F. R. Cook	1020	15	60	ss	Mc		2-10-54			4	D	
9	John Newman	900	50	93	ss	Mc	65	10-12-57	8	18	4	D	
10	Martin Schmelzer	990	20	90	ss	Mc		4- 4-55			5	D	
11	Glen Howe	1000	45	130	ss	Mc	90				5	D	
12	Larry Loving	840	32	90	ss	Mc	3	7- 5-57	4	85	8	D	
13	Paul Hamm	840	43	85	ss	Mc	21	5-10-58	10		4	D	
14	C. W. Hengst	850		64	gr	Gla	30	5- 5-55	12	2	5	D	
15	Burl Poling	900	70	90	ss	Mc		3-23-53			4	D	
16	Raymond Figgins	930	70	192	ss	Mc	104	3-29-56	10	26	6	D	
17	Albert Mohler	940	30	117	ss	Mc	70	3-24-56	5		6	D	
18	Anchor-Hocking Glass Co.	830	18	94	sd & gr	Gla	9	4-12-58			12	Ind	
19	Robert Conners	880	80	148	ss	Mc		10-29-54			5	D	
20	Hugh Gilmore	900	8	131	ss	Mc		11-14-55			5	D	
21	Archie Chaney	850		133	sd	Gla	12	5- 5-59	20	4	4	D	
22	Verlon Kramer	870	56	80	ss	Mc	25	1-15-58	12	15	4	D	
23	Charles Wagner	1020		63	sd & gr	Gla	17	2-20-58	20	1	5	D	
						Hocking Township							
1	David Acton	970	5	215	sh	Mc	30	8-28-58	7	177	6	D	
2	Bigum's Upholstery	910		125	sd & gr	Gla		10- 1-49	5		5	D	
3	Charles Schoolery	900		90	sd & gr	Gla		5- 1-53			4	D	
4	Harold Cupp	880	25	80	sh	Mc		12- 3-53			4	D	
5	Wayne Reese	1000	21	91	ss	Mc	40	4- 7-56	10	25	5	D	
6	Lancaster Country Club	920	120	312	ss	Mc	15	1-27-58	100	95	8		
7	Arthur Dennis	980	90	220	ss	Mc	80	8-15-55	5	5	4	D	
8	City of Lancaster	1000		42	sd	Gla		6-11-53			4	D	
9	Harold Beavers	960		51	sd	Gla	16	10-21-57	6	1	4	D	
10	Alva Hanna	1020	83	225	ss	Mc	165	11-12-56	10	30	5	D	
11	Bennett Wildman	1120		28	gr	Gla	12	4-23-57	20	8	5	D	
12	Robert Hollar	1000	18	250	ss	Mc	125	4-30-56	10	1	5	D	
13	Merle Asbel	1030		55	sd & gr	Gla		6- 7-54			4	D	
14	Homer Beavers	1100		52	sd & gr	Gla		1- 9-56	10	10	4	D	

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS, continued

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic unit	Water level: Below land surface (feet)	Water level: Date	Yield: Rate (g.p.m.)	Yield: Drawdown (feet)	Diameter of well (inches)	Use	Remarks
						Hocking Township							
15	Everett Hammel	1100	10	206	ss	Mc	167	10-20-56	6	30	5	D	
16	Henry Devault	1040	5	140	ss	Mc	82	2-28-59	8	25	5	D	
17	Lawrence Woltinger	1000		44	sd & gr	Gla						D	
18	State of Ohio	1000	20	402	ss	Mc		11- -41			16		
19	Karl Hoffman	875		175	sd & gr	Gla	40	3-25-48			4	D	
20	Carl Dysler	850		71	gr	Gla	20	10- 2-53			4	D	
21	Joe Joos	960		80	sd	Gla	38	5-28-55	8	2	4	D	
22	Emil Chase	1050	20	150	ss	Mc					5	D	
23	Grant Thomas	1030	34	145	ss	Mc	45	8-27-54			4	D	
24	City of Lancaster			90	sd & gr	Gla	9	6-16-56	600	9	20		
F-3	City of Lancaster	820		90	sd & gr	Gla		8-12-55			36		State observation well.
						Liberty Township							
1	Cleve Blouser	924		76	gr	Gla	44	11- 1-54	12	1	4	D	
2	Farrell	1065		92	gr	Gla	35	10-27-57	12	10	4	D	
3	Village of Baltimore	870		175	gr	Gla	38	6-26-53	400	87	10	D	
4	O. Cheadle	840		87	sd	Gla	45	1-21-56	20		5	D	
5	Jake Ditwider	890		161	gr	Gla	45	4-26-56	12	10	4	D	
6	Robert Deeter	845		91	gr	Gla	60	7-26-54	12	1	5	D	
7	Taywell Hizey	965	109	135	ss	Mc	30	10-30-56	20	1	4	D	
8	John Kistler	863		78	gr	Gla	61	4-25-57	15	5	4	D	
9	Fred Miller	938		76	sd	Gla	37	3-20-54	5	44	5	D	
10	Pete Moore	830		58	gr	Gla	4	7-21-55	15	1	4	D	
11	Merle McDaniel	905		107	gr	Gla	45	7-21-55	15	1	4	D	
12	Russel McDaniel	880		100	gr	Gla	60	5- 1-54	3	30	4	D	
13	Charles Poff	995	225	270	ss	Mc	65	2-23-54	10		5	D	
14	Wayne Taggert	980	155	190	ss	Mc		11-21-52	7		4	D	
15	Arthur Vanardaler	885		98	gr	Gla	40	6-27-55	6	1	4	D	
16	Andrew Wagner	865		73	gr	Gla	12	1-15-57	18	40	5	D	
17	John Scott	943		69	sd & gr	Gla	30	2-10-55	10	7	5	D	
18	Bob Garnall	1025	234	254	ss	Mc	36	3- 4-57	12	36	5	D	
19	Adam Poff	890		93	gr	Gla	41	7-28-59	15	20	5	D	
						Madison Township							
1	Fred Hosler	870		60	sd	Gla		11-10-53			4	D	
2	Merle McBowam	850		110	sd	Gla		8-10-50			4	D	
3	Archie Hummel	850		42	gr	Gla		2- 3-54			4	D	
4	E. L. Moon	810	10	310	ss	Mb		9-18-50			5	D	
5	Don Collison	1050	14	160	ss	Mc		9- 1-54			6	D	

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS, continued

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed		Water level		Yield		Diameter of well (inches)	Use	Remarks
					Character of material	Geologic unit	Below land surface (feet)	Date	Rate (g.p.m.)	Drawdown (feet)			
						Madison Township							
6	Carl Bussert	1025		105	sd	Gla		8-28-50			4	D	
7	Clyde Morgan	970	20	182	ss	Mc	157	9-13-56	5	5	4	D	
						Pleasant Township							
1	Paul Meister	910		76	sd & gr	Gla		2- 9-53			5	D	
2	W. M. Wildermuth	920	112	157	ss	Mc		55-21-55			4	D	
3	Evert Keller	920	22	64	ss	Mc		3- 1-56			4	D	
4	Donald Leith	890		101	gr	Gla		4-26-56			5	D	Well flows at 5 gpm.
5	Blanch Kimmel	920	22	38	ss	Mc	28	2- 2-53	10	1	4	D	
6	Howard Rowles	900		90	gr	Gla		8-24-54			4	D	
7	Howard Rowles	920	91	114	ss	Mc	35	5-27-57	20	75	6	D	
8	Richard Lysinger	1060	86	98	ss	Mc	35	6-20-54	10	5	4	D	
9	Rodger McCune	1060		78	sd & gr	Gla	24	8-27-57	20	30	5	D	
10	Hanning's	1040	76	154	ss	Mc	33	3-22-57	5	67	4	D	
11	South-Central Cafe	1030	25	209	sh	Mc	50	11-28-57	20	6	8		
12	Ethel Boggess	940		68	gr	Gla	4	4- 8-58	10	45	6	D	
13	Bill Wother	980		109	gr	Gla	60	9-19-57	5	40	4	D	
14	Al Frasdre	1020	35	100	ss	Mc		4-13-55			4	D	
15	Walter Nelson	1040	36	107	sh	Mc	75	6-20-57	14	10	4	D	
16	Clarence Wallace	960		79	sd & gr	Gla	3	7-10-57	5	1	6	D	
17	Paul Markwood	920		60	sd & gr	Gla	30	6-15-37	30	15	5	D	
18	H. T. Tobias	910	80	97	ss	Mc		3-20-53			4	D	
19	George Kinzler	920	5	244	ss	Mc		10-20-54			5	D	
20	Robert Grandstaff	880		97	gr	Gla		6- 1-52			4	D	
21	Walter Kixley	980	ss	115	ss	Mc		9-17-53			4	D	
22	Mary Reynolds	900		118	gr	Gla		10-10-53			4	D	
23	Maple Grove Cemetery	930		125	sd	Gla	46	2- 7-59	20	1	5	D	
24	Richard George	900	14	65	ss	Mc	35	1-25-56	20	10	7	D	
						Richland Township							
1	Lawrence Goodman	990		80	gr	Gla	5	10-10-56	40	58	6	D	
2	Lester Peters	960	94	100	ss	Mc	35	2- 8-55	15	20	5	D	
3	Ira Peters	940		74	gr	Gla	4	11- 5-54	17		8	D	Well pumped dry.
4	John Drumm	1000		97	gr	Gla	30	4-26-56	10	1	4	D	
5	Frank Wright	840	109	114	ss	Mc		8- 2-55	20		5	D	
6	R. E. Wickliff	1040	42	120	sh	Ml	50	9-29-49	5		5	D	Well pumped dry.
7	Wingert Baker	1060		110	gr	Gla	8	10- 7-49	20	55	5	D	
8	V. W. Clarkson	1020	60	85	sh	Ml	18	11-28-56	15	1	6	D	
9	Viola Pickering	1040	12	220	sh	Ml		1-30-54	1		6	D	

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS, continued

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed		Water level		Yield		Diameter of well (inches)	Use	Remarks
					Character of material	Geologic unit	Below land surface (feet)	Date	Rate (g.p.m.)	Drawdown (feet)			
Richland Township													
10	J. A. Getchen	1050	33	222	sh	Ml	50	5- 5-54	2	48	5	D	
11	C. F. Shaeffer	1020	24	125	sh	Ml	65	7-10-58	3		5	D	Well pumped dry.
12	Dale Winegardner	1000		56	gr	Gla	20	7- 1-52	5		5	D	Well pumped dry.
F-1	C. E. Howdyshell	980		110	ss	Ml					4		State observation well
Rush Creek Township													
1	Cora Shaw	1020	27	60	ss	Ml	25	1- 7-53	10	1	6	D	
2	Harley Thomas	1070	7	259	ss	Ml	170	1- 8-53	2		6	D	
3	Grafie Turner	830	30	94	ss	Ml	33	1-16-56	15	2	6	D	
4	Board of Public Affairs	790		71	sd & gr	Gla	11	11- 4-54	50	12	8		
5	T. E. Ditto	840	15	210	ss	Mc	50	1-14-57	2		6	D	
6	Wayne McLaughlin	940	8	165	sh	Ml	50	1- 7-53			6	D	
7	Lester Shand	950		260	sh	Mc	100	10-18-49	3	25	6	D	
8	Clyde Bauersock	980	45	87	ss	Ml	45	12- 4-55	20	1	5	D	
9	Phil Tschappat	820	54	113	sh	Ml	43	9- 3-52	20	17	6	D	
10	Phil Tschappat	810	13	80	ss	Ml	20	11-25-53	8	1	5	D	
11	Bremen Cheese	790	45	100	ss	Mc	10	7-22-54	2		8		
12	George Kelsey	865	25	121	ss	Ml	117	11-24-55	6		5	D	Well pumped dry.
13	Elmer Miller	835		152	sd	Gla	56	10-10-57	25	1	4	D	
14	Walter Wiesman	1050	17	246	ss	Ml	96	12-29-54	7		5	D	A. Well pumped dry.
Violet Township													
1	George Walker	830		66	sd & gr	Gla	38	2-10-54	100	28	4	D	
2	Allen Johnson	911		160	sd & gr	Gla	75	11-10-56	15	20	5	D	
3	Noah Moore	1030		92	gr	Gla		1- 3-53	10		5	D	
4	Nelson Davis	855		95	sd & gr	Gla	28	7-30-54	6	1	6	D	
5	Earl Korbett	890	61	100	sh	Ms	20	12-23-53	15	15	5	D	
6	Village of Pickerington	860	50	118	sh	Mb	43	2-28-54	75	38	10	P	
7	Pickerington Creamery	870	36	58	ss	Mc	34	9-18-54	130	7	8	P	
8	Neil Painter	795		124	gr	Gla	32	3-29-55	6		6	D	
9	William Diley	840		150	gr	Gla	115	1-17-55	10	6	5	D	
10	Village of Pickerington	860	90	104	sh	Mbe	8	5- 9-59	47	20	4	D	
11	Henry Inman	855	26	120	sh	Mbe	20	5-11-59	60	20	5	D	
12	Earl Myers	800		100	sd & gr	Gla		2-19-59	30		4	D	Static level 18' above ground level.
13	Kite Construction Co.	850	40	94	ss	Mb	36	5- 6-58	10	4	4	D	
14	Zeller	838		179	gr	Gla	55	3-17-52	6	5	6	D	
15	Alspaugh	780		117	sd & gr	Gla	38	11-19-54	6	1	4	D	
16	James Bickle	795	28	99	sh	Mbe	30	6- 8-57	1		4	D	Well pumped dry.
17	Arthur Houser	830		78	gr	Gla	45	6-11-57	18	14	5	D	

Table 8. - RECORDS OF WATER AND STATE OBSERVATION WELLS, continued

Well number	Owner or Name	Elevation at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing bed		Water level		Yield		Diameter of well (inches)	Use	Remarks
					Character of material	Geologic unit	Below land surface (feet)	Date	Rate (g.p.m.)	Drawdown (feet)			
Violet Township													
18	Harold Porter	945		136	gr	Gla	80	7-11-58	30		5	D	
19	James Carruthers	840		99	gr	Gla	8	4-21-59	10		5		Well pumped dry.
20	Higgins	945		48	gr	Gla	33	8-10-54	10	1	4	D	A
Walnut Township													
1	Kermit Berry	865	125	132	sh	Mc	28	1-15-55	7	5	4	D	
2	Harry Lewis Inc.	900		146	gr	Gla	31	12- 8-53	20	6	5	I	
3	Ralph Hanna	900		136	gr	Gla	50	6-20-54	5	25	4	D	
4	Charles Fenstermaker	880		87	gr	Gla	10	6- 6-55	100	1	6	D	
5	Jim Ervin	1000	43	100	sh	Ml	55	11-15-55	20	5	5	D	
6	Chapdelaine	1050		182	gr	Gla	50	12-15-52	4		6	D	Well pumped dry.
7	Charles Camp	950		56	gr	Gla	40	7-10-53	15	2	5	D	
8	Click	920		73	sd & gr	Gla	8	10- 9-53	15	43	5	D	
9	Don Barricklow	900		93	gr	Gla		6- 2-54	15	8	4	D	Static level 2' above ground surface
10	Paul Thomas	900	185	230	ss	Mc	60	10-27-57	25	25	5	D	
11	Dale George	990		169	gr	Gla	53	9-23-57	18	6	5	D	
12	Jessie Jewell	900		133	sd & gr	Gla	10	5-20-55	5	50	4	D	
13	Willis George	940	34	41	ss	Ml	15	2- 7-56	12	2	4	D	
14	C. E. Bower	900	70	76	ss	Mc	25	12-29-51			4	D	
15	Howard Cherpp	910		38	gr	Gla	8	6-12-58	15	1	4	D	
16	Russell Bowers	920		217	gr	Gla	70	7-30-54	15	1	4	D	

Chapter 9

ECONOMIC GEOLOGY

BUILDING STONE

RACCOON MEMBER

The siltstones exposed in the lower part of the Raccoon member occur in massive beds as much as 2 feet thick along some of the streams in northwestern Bloom Township. They are hard, uniform in texture, and range in color from light olive gray (5 Y 6/1) to light bluish gray (5 B 7/1) on the fresh surface. Formerly, they were quarried for building stone at Lithopolis. Stone from the Raccoon member was used in building the Wagnall Memorial at Lithopolis and is a potential source of flagstone readily accessible to the Columbus area.

BLACK HAND MEMBER

Extensive quarrying of the Black Hand sandstone was carried on in the Hocking Valley area in the latter part of the nineteenth century and possibly in the early part of the twentieth. At present the quarries are abandoned, but the supply of sandstone in them is nearly inexhaustible.

The quality of the stone has been described by Hyde as follows:

> The stone which is yielded by the sandstone is unexcelled in quality for some purposes, especially for massive work such as bridge abutments, and retaining walls. Its durability is unquestioned. Since the abandonment of the canal, the wooden gates of the locks have rotted and fallen away and their hinges are thickly coated with rust; the mortar in the lock walls is crumbling and the loosened blocks of stone are being pushed from their place by the young trees growing behind them, but the tool marks on their sides are almost as sharp as when they were taken from the quarries more than 70 years ago.
>
> The stone to be used for building purposes needs careful selection but that it can be so adapted with success is attested by the City Hall and County Court House at Lancaster, the former of rough dressed stone, the latter smooth dressed. It is apt to carry unsightly blotches of iron which are disastrous to architectural effects unless selection is rigidly enforced. (Hyde, 1912, p. 210, 211)

Except for a small quarry located at the northern end of Chestnut Ridge in the SW$\frac{1}{4}$ of section 18, Bloom Township, the sandstone was obtained exclusively from quarries located south and southeast of Lancaster in Berne Township. All of these quarries are located in the Sugargrove lobe, and all but the Sharp quarries, which lie west-southwest of Sugargrove, are located east of the Hocking River.

The Sugargrove lobe in central and eastern Berne Township (fig. 22), offers the best quality of sandstone. Here the Black Hand member is massive, uniform in texture and color, and relatively free of hydrous iron oxide bands. The sandstones of the lobe consist largely of medium- to coarse-grained sand and for the most part are free of fine-grained sand and pebbles. Because of the steep eastward dip of the Sugargrove lobe, however, the amount of overburden might be prohibitive more than a short distance east of the Hocking River.

SHALE

The Bedford shale is presently quarried in eastern Franklin County, where it is used as a source of clay in the production of clay products. Outcrops of the Bedford occur in Fairfield County in ravines tributary to the valley of Walnut Creek in sections 6, 7, and 18, Bloom Township, and in the bank of Walnut Creek in the SW$\frac{1}{4}$ of section 33, Violet Township. The Bedford is mentioned here as a potential shale resource, but one of doubtful value in the immediate future.

PEAT

The only part of Fairfield County in which peat deposits are likely is on the western slope of the divide between the Hocking and Scioto Rivers, on the western edge of the county. In this area Dachnowski (1912, p. 58-59) reports the occurrence of peat on the former J. A. Madden farm, in section 26 of Amanda Township. This deposit was found to have a high ash content, moderate thermal value, and a higher-than-average content of nitrogen for peat in Ohio. At the time of sampling (1912, or slightly earlier) the deposit was not considered commercially valuable as fuel because of the high ash content.

A poor grade of peat, usable only as a soil reconditioner, is produced at present from a Wisconsin-age peat bog located north of Canal Winchester in western Violet Township.

LIMESTONE

The only limestone exposed in Fairfield County crops out in some of the hills of the eastern part of the county. It has been identified tentatively as one of the Mercer limestones of Pottsville (Pennsylvanian) age. The limited thickness of the limestone, less than 2 feet, and the relatively small area of occurrence, prevent this stone from being commercially valuable.

A thin bed of what is probably Maxville limestone of late Mississippian age crops out in a ravine just east of the Fairfield-Perry County line, in the SW$\frac{1}{4}$ of section 26, Reading Township, Perry County. However, no exposures have been reported in Fairfield County. If the Maxville is present in the county, it probably is extremely thin and of no commercial importance.

BRINE

Brine in commercial quantities has not been reported in Fairfield County, although brine is known to be present in rocks underlying at least one part of the county. Lamborn (1952) reports the presence of brine in the zone of the "Blue Lick" water, or St. Peter sandstone (Ordovician), in section 30, Amanda Township, where the brine was taken from a depth of 3263 feet (2343 feet below sea level) in the Emmet Brown No. 1 well. Analysis of the brine showed the total dissolved solids to be 125.922 grams per kilogram, or 137.13 grams per liter (Lamborn, 1952, p. 19).

COAL

A small amount of coal is known to be present in Pennsylvanian-age rocks of the higher hills in Richland, Rush Creek, and Berne Townships, in the eastern part of Fairfield County. However, because the thickness and areal extent of the coal are relatively insignificant, the summary report on Ohio coal resources (Brant and DeLong, 1960) reports no coal reserve for the county.

SAND AND GRAVEL

OCCURRENCE

Fairfield County contains large quantities of sand and gravel of potential economic importance. These deposits, mostly of Wisconsin age, occur scattered throughout the county as outwash terraces, kames, eskers, and a kame terrace.

Most significant of the producing deposits are the Wisconsin gravel terraces. Large active sand and gravel pits are found in the Carroll lower constructional terrace in the part of the Hocking Valley south of Lancaster, and in the late Wisconsin terrace in the valley of Blacklick Creek in northwestern Violet Township. The gravel of this late Wisconsin terrace, which is generally of good quality, is more uniform in size and contains fewer deleterious fragments than does kame gravel in the county. Also, it lacks the thick overburden which characterizes the Illinoian and earlier Wisconsin terrace materials. In the abandoned valley immediately east of Lancaster a sand and gravel pit is located in the higher, older Lancaster terrace of Wisconsin age. Although the quality of the gravel in this terrace appears to be as good as that of the gravel in the lower Wisconsin terrace, the presence of a thick overburden (as much as 8 feet) of weathered gravel capped by silt makes the gravel in this terrace far less profitable to excavate commercially.

Abundant gravel is also present in kames of Wisconsin age, which, although present in several places in Fairfield County, have been excavated only near Carroll and east of Millersport. Other kames, which should also provide economic supplies of sand and gravel, are located in the following areas: adjacent to the Canal Winchester moraine west of Pickerington; on the Johnstown moraine east of Carroll; on the Cedar Hill moraine east of Marcy and south of Cedar Hill; and associated with the Rushville moraine, near Oakthorpe. It is possible that some of these kames, especially those near Oakthorpe, may be of somewhat less value, because the presence of sandstone and shale near or at the surface in these areas suggests that the amount of deleterious materials present in the gravel may be unusually high and, also, because a cap (overburden) of silt or till is present in some places.

The two eskers in the county are probably of little economic value, for the esker north of Cedar Hill is very small, and the only large esker, the Pickerington esker lying between Pickerington and Basil (Baltimore), appears to be mostly sand. Furthermore, numerous buildings and a highway (State Route 256) have been built on this esker, so that areas available for excavation are limited.

One of the largest gravel deposits in Fairfield County is the kame terrace west of Carroll, but it has not been excavated to a very large extent, partly because the gravel is so coarse that it has to be crushed before marketing. The outwash plain originating from this Carroll kame terrace, which becomes the Carroll outwash terrace farther down the Hocking Valley, extends from south of Carroll to within a mile of the Lancaster city limits. This deposit has not been extensively exploited for sand and gravel, though some pits are located in this feature near Hooker and north of the Methodist campground. Because this deposit lies beneath valuable farmland and appears to be thin, it probably will never be a significant source of sand and gravel.

Sand and gravel in Fairfield County also is produced from Illinoian terraces. Pits have been opened in these terraces in the vicinity of Bremen in Rush Creek Township and along the bluffs of the Hocking Valley in Berne Township. Except in locations like these, where natural erosion has removed a part of the surface soil, Illinoian terrace gravels are uneconomic to remove because of the thick overburden created by the deep soil characteristic of all Illinoian deposits. This soil, locally capped by silt, makes up an overburden which may be as much as 12 feet thick.

PRODUCTION AND USE

Production of sand and gravel in Fairfield County for the ten-year period 1951-60 is shown in tables 9 and 10. As shown in these tables, most of the sand and gravel produced in the county was used for building and paving purposes. Sand produced by the Keener Sand and Clay Co. from Illinoian outwash deposits near Bremen also was used for foundry purposes.

A directory of companies producing sand and gravel in the county in 1960 is given in table 11.

Table 9. - PRODUCTION OF SAND IN FAIRFIELD COUNTY, OHIO, 1951-60, IN TONS (From Klein, 1952; Alloway, 1953-56; and Kefaufer, 1957-61)

Year	Uses					
	Foundry	Building	Paving	Engine	Other	Total
1951	9,747	34,994	5,944	500	15,012	66,197
1952	5,893	48,375	14,998	--	--	69,266
1953	6,406	27,432	14,585	--	--	48,423
1954	4,646	33,130	17,024	--	--	54,810
1955	4,854	19,993	41,672	--	--	66,519
1956	4,482	41,294	11,480	--	--	57,256
1957	--	31,320	46,223	--	--	77,543
1958	4,956	45,640	40,884	--	6,302	97,782
1959	8,103	64,145	112,385	--	5,725	190,358
1960	--	52,313	59,685	--	--	111,998

Table 10. - PRODUCTION OF GRAVEL IN FAIRFIELD COUNTY, OHIO, 1951-60, IN TONS
(From Klein, 1952; Alloway, 1953-56; and Kefaufer, 1957-61)

Year	Uses			
	Building	Paving	Other	Total
1951	39,671	56,629	8,734	105,034
1952	20,476	93,324	8,121	121,921
1953	18,705	84,781	7,125	110,611
1954	33,664	76,798	6,499	116,961
1955	21,287	84,483	92,633	198,403
1956	29,580	132,318	--	161,898
1957	26,046	122,240	2,532	150,818
1958	27,234	125,291	12,480	165,005
1959	27,243	191,346	11,994	230,583
1960	32,767	96,795	37,936	167,498

Table 11. - DIRECTORY OF SAND AND GRAVEL PRODUCERS IN FAIRFIELD COUNTY, OHIO, 1960
(From Kefaufer, 1961)

Name and address	Name of pit	Township	Geologic formation
F. H. Brewer Co. P. O. Box 372 Lancaster, Ohio	F. H. Brewer Co. (sand and gravel)	Berne	Undifferentiated Pleistocene glacial outwash
Febus Gravel Co. 133 Pershing Drive Lancaster, Ohio	Febus Gravel Co. (sand and gravel)	Berne	Illinoian glacial outwash
R. and M. Sand and Gravel Co., Inc. Reynoldsburg, Ohio	R. and M. Sand and Gravel Co., Inc. (gravel)	Violet	Wisconsin glacial outwash
Sargent Gravel Co. 219 Wyandotte St. Lancaster, Ohio	Sargent Gravel Co. (sand and gravel)	Berne	Illinoian glacial outwash
Homer Taylor and Son, Inc. 1011 E. 6th Ave. Lancaster, Ohio	Homer Taylor and Son, Inc. (gravel)	Berne	Wisconsin glacial outwash

OIL AND GAS

OCCURRENCE

A number of named subsurface beds of Fairfield County contain oil and gas, but only three of these, the Berea (Mississippian), Newburg (Silurian), and "Clinton" (Silurian) are economically important. Of these three the "Clinton," which contains mainly gas, has been by far the most productive. The stratigraphically lowest oil-bearing zone drilled in the county is in the St. Lawrence (formerly called Trempealeau) formation of Cambrian age. It has been reached by at least five wells in Amanda and Violet Townships, one well of which produced a small amount of oil.

The Berea sandstone in Fairfield County is an eastward-dipping relatively thin blanket-type sandstone that is reported to be in nearly every well drilled east of its outcrop area in Amanda, Bloom, and Violet Townships, on the western edge of the county. The depth to the top of this sandstone as noted on drillers' records ranges from 126 feet in Amanda Township, in western Fairfield County, to 823 feet in Richland Township, in the eastern part of the county (table 12). Driller' logs indicate that the Berea ranges in thickness from 2 feet to 58 feet in wells throughout the county. At its outcrop in Bloom Township the Berea ranges in thickness from 3 to 8 feet, and in general it thickens eastward to about 40 feet on the eastern edge of the county (Pepper and others, 1954, pl. 1). The Berea consists of very fine grained medium light gray to pale reddish brown or very pale orange quartzose sandstone. It commonly contains pyrite and marcasite and in some places contains a small amount of mica. Cuttings from at least two wells, in section 30 of Amanda Township and section 15 of Walnut Township, indicate that the brown to orange sand is slightly calcareous.

Table 12. - RANGES IN THICKNESS AND IN DEPTH TO TOP OF THE BEREA AND "CLINTON" SANDSTONES IN FAIRFIELD COUNTY, OHIO
(Compiled from drillers' records on file with the Ohio Division of Geological Survey)

Township	Berea sandstone				"Clinton" sandstone			
	Range in thickness (ft)		Range in depth to top (ft)		Range in thickness (ft)		Range in depth to top (ft)	
	From	To	From	To	From	To	From	To
Amanda	5	--	126	--	--	--	1705	--
Berne	2	50	400	713	2	53	1955	2560
Bloom	50	--	300	--	--	--	1750	--
Clear Creek	--	--	--	--	--	--	--	--
Gore[1]	8	40	430	787	9	38	2033	2509
Greenfield	16	28	409	542	4	16	1946	2116
Hocking	10	14	395	548	25	--	1982	--
Liberty	8	26	252	470	1	35	1742	2032
Madison	4	25	394	653	--	--	--	--
Pleasant	15	42	444	727	2	33	2024	2469
Richland	10	45	585	823	12	45	2302	2682
Rush Creek	6	58	570	810	4	56	2263	2745
Violet	--	--	--	--	3	--	1315	1612
Walnut	7	35	377	660	2	39	1952	2388

1. Gore Township is the old name of the area in T. 13 N. that comprises the 12 southernmost sections of the present Berne Township.

The term "Newburg zone" is a drillers' name for a porous oil- and gas-producing zone in Silurian dolomite thought to be at the top of the Niagaran series and base of the Cayugan series in Ohio. In Fairfield County, as in Cuyahoga, Wayne, and Licking Counties, oil in the Newburg zone is produced from what are believed to be buried reefs. In Walnut Township of Fairfield County, oil from the Newburg is produced in the New Salem oil pool, which has a nearly symmetrical structure caused by a buried elliptical mound or reef that is about 80 feet thick and almost a mile long (Floto, 1955, p. 47). Probably because of differential compaction, this structure is reflected in stratigraphically higher units, as shown by a structure of 50 feet on the top of the "Big Lime" of drillers' usage. Drillers' records indicate that the average depth to the top of the Newburg zone in the county is 1975 feet.

The "Clinton" sandstone is a drillers' term for a lower Silurian sandstone that is equivalent in age not to the Clinton formation of New York, but to the Cabot Head-Thorold shale and sandstone sequence of western and central New York (Rittenhouse, 1949). The "Clinton" in Fairfield County is a fine-grained compact sandstone that ranges in color from gray to brick red. In general, however, it has no definite identifying characteristics, other than its compact nature and stratigraphic position, to distinguish it from other oil- and gas-bearing sandstones. It is reported by drillers to be an eastward-dipping bed that is present in nearly every well drilled to its stratigraphic position in Fairfield County. Drillers' logs indicate that the depth to the top of the sandstone ranges from 1315 feet in Violet Township, in northwestern Fairfield County, to 2302 feet in Richland Township, on the eastern edge of the county (table 12). The thickness of the sandstone in the county as logged by well drillers ranges from 2 to 56 feet. Farther north in Ohio, in the vicinity of Canton and Massillon, the "Clinton" consists of three separate sand bodies, the "stray Clinton," the "red Clinton," and the "white Clinton," but in Fairfield County no threefold division of the sandstone is reported.

Gas and oil in the "Clinton" sandstone of central Ohio are reported by Rittenhouse (1949) generally to occur in relatively small discontinuous lenses at several stratigraphic levels. Rittenhouse postulates that these sand lenses probably are near-shore beach, bar, and tidal channel deposits and that the gas and oil contained in them occur in zones of favorable porosity at the contact between the individual sand bodies of overlapping strand lines. Therefore, the accumulation of gas and oil in the "Clinton" of central Ohio is related not to local structure, but principally to the original distribution of the sand bodies and to the degree of cementation.

The distribution of oil and gas pools in Fairfield County, as indicated by maps of the Subsurface Geology Section of the Ohio Division of Geological Survey, is shown in figure 63.

HISTORY OF PRODUCTION

Gas was first produced in Fairfield County in 1887, with the opening of the North Berne pool in northeastern Berne Township. Subsequent discoveries of gas occurred rapidly, and by the early part of this century, gas pools were known to underlie much of the eastern half of Fairfield County. The largest of these was the Sugargrove pool, centered in Berne Township. With the exception of the Rushville pool, all gas in eastern Fairfield County has been produced from the "Clinton" sandstone of the driller. In the Rushville pool, gas is produced from the "Clinton," but in a few wells located in section 5, Rush Creek Township, gas is found in the Berea sandstone. In the western part of the county, gas pools have been developed only in south-central Hocking and north-central Madison Townships. The producing zone here is the Berea.

The first oil in Fairfield County was discovered in the "Clinton" sandstone at Bremen in 1907. A flurry of activity led to the development of the Bremen oil pool, which consists of a number of smaller pools occupying much of Rush Creek Township. The early development of the Bremen pool has been reviewed in detail by Bownocker (1910). In 1910 the Oakthorpe pool in west-central Richland Township was opened,

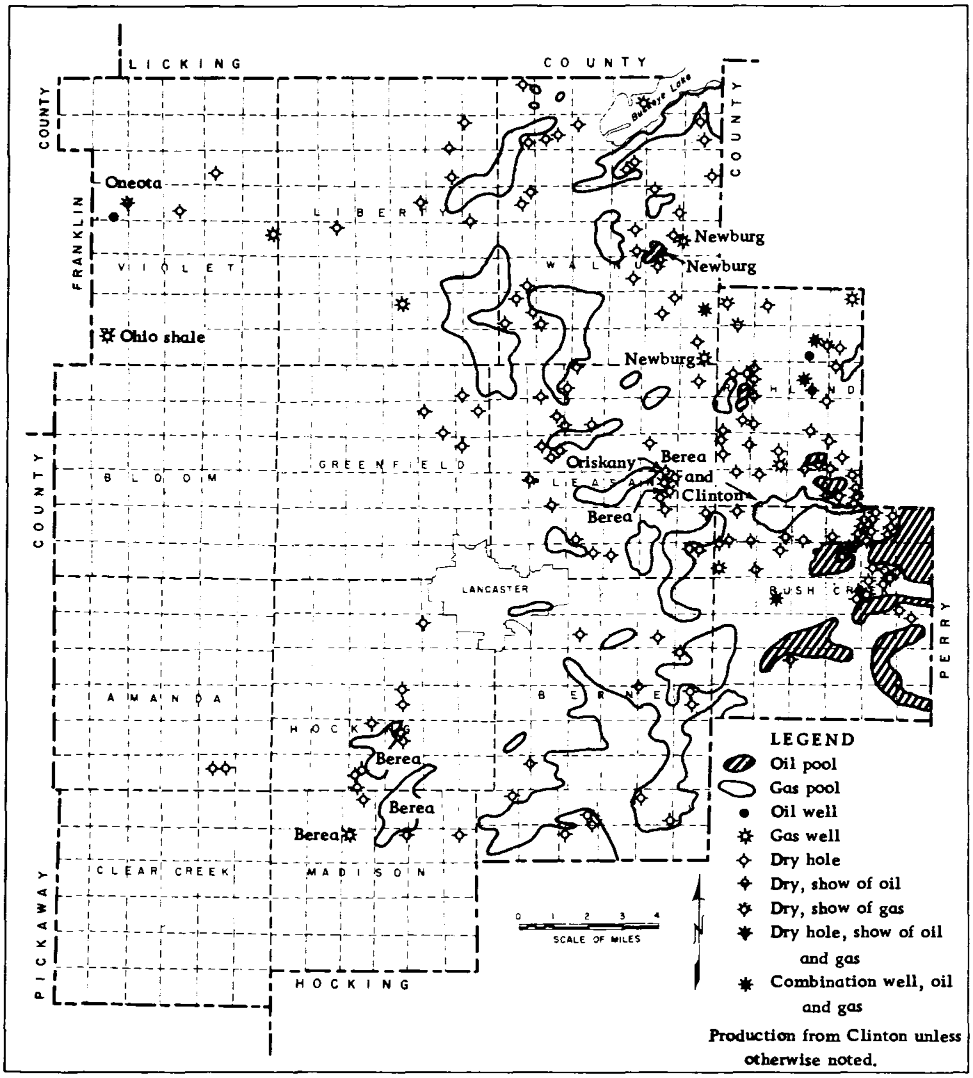

Figure 63. - Oil and gas pools in Fairfield County.

and in 1918 the Rushville pool in southeastern Richland Township was developed. In 1960 the discovery well of the North Rushville pool, in section 16 of Richland Township, was completed. The "Clinton" sandstone is the producing zone in all three pools. The only other significant oil pool in Fairfield County is the New Salem pool, opened in 1940 in sections 14 and 23 of Walnut Township. Production here is from the so-called Newburg zone. Some oil was produced from a well drilled in 1960 to the St. Lawrence (Trempealeau) formation in section 8 of Violet Township, but the amount of oil produced was extremely small.

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APPENDIX -- MEASURED STRATIGRAPHIC SECTIONS

O. G. S. 7543

Stratigraphic section of Mississippian and Pennsylvanian strata in sections 11 and 12, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured along northwest-southeast road from a point in the NW¼ SE¼ of section 11 approximately a tenth of a mile south of the 816-foot road corner to the hilltop at the 1068-foot road corner in the SE¼ SW¼ of section 12.

	Feet
PENNSYLVANIAN SYSTEM	
Pottsville Group	
20. Sandstone, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4); consists of fine- to medium-grained subangular sand; micaceous, massive, extremely friable; basal contact covered.	1.0
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
19. Covered interval; Vinton float in lower 3 feet.	7.0
18. Siltstone, yellowish gray (5 Y 7/2), thin- to medium-bedded, finely laminated, micaceous, hard, intermittently exposed; basal contact covered	130
ALLENSVILLE MEMBER	
17. Covered interval; Allensville float in lower 5 feet.	7.0
16. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4); consists of subangular sand varying from fine- to coarse-grained, but predominantly medium-grained; medium-bedded, friable; irregular hydrous iron oxide bands; scattered brachiopods and crinoid columnals; base not seen	6.7
BYER MEMBER	
15. Covered interval; fossiliferous Byer float with brachiopods, fenestellid bryozoans, and crinoid columnals in lower 10 feet.	14.4
14. Sandstone, dusky yellow (5 Y 6/4); consists of very fine grained subangular sand with rare grains of coarse sand; thin- to medium-bedded, soft; basal contact sharp	22.0
BERNE MEMBER	
13. Sandstone, dark yellowish orange (10 YR 6/6), conglomeratic, poorly sorted; consists of subangular fine- to coarse-grained but predominantly medium-grained sand and pebbles usually less than 1/4 inch, but occasionally as large as 1/2 inch in diameter; massive, friable; hydrous iron oxide bands; basal contact sharp.	1.8
12. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), poorly sorted, fine- to coarse-grained, predominantly medium-grained; sand subangular; quartz overgrowths common; hard, massive; basal contact sharp . . .	1.5
11. Mudstone, moderate yellowish brown (10 YR 5/4); weathers to medium light gray (N6) clay; silty, thin-bedded, soft, crumbly; basal contact gradational	1.3
10. Sandstone, light brown (5 YR 5/6), poorly sorted; consists of fine- and medium-grained sand; hard, massive; hydrous iron oxide bands; base covered	1.0
9. Covered interval	6.0
8. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), irregularly iron-stained, poorly sorted; consists of medium- to coarse-grained subangular to subrounded sand with some fine-grained sand; massive, extremely friable; basal contact sharp	1.0
7. Sandstone, dark yellowish orange (10 YR 6/6), fine- to medium-grained; sand subangular; massive, slightly friable; hydrous iron oxide bands	3.0
6. Siltstone, dark yellowish orange (10 YR 6/6), slightly sandy, soft, massive; basal contact gradational	0.3
5. Siltstone, light olive gray (5 Y 6/1), slightly sandy, massive, soft; basal contact sharp.	0.3
4. Sandstone, light brown (5 YR 5/6); consists of very coarse grained subangular sand and occasional quartz pebbles up to 1/4 inch in diameter; massive, friable; at the top a hydrous iron oxide band ranging in thickness from 1/4 inch to 1/2 inch; basal contact sharp	1.0
3. Sandstone, moderate yellowish brown (10 YR 5/4) to dark yellowish orange (10 YR 6/6), very fine grained, medium- to thick-bedded, hard; hydrous iron oxide bands; a single, poorly preserved brachiopod found; basal contact sharp.	5.4
2. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted; consists of subangular fine- to coarse-grained sand; massive, very friable; basal contact sharp. . . .	2.0

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

	Feet
1. Sandstone, light brown (5 YR 5/6); consists of poorly sorted, predominantly medium-grained, subangular sand with occasional pebble washes up to 8 inches thick; pebbles range from 1/16 to 1/4 inch in diameter; somewhat friable, massive, crossbedded; base covered.	5.0

Elevation at base of section 831 feet (hand level)

O. G. S. 10591

Stratigraphic section of Mississippian strata in section 1, Madison Township, Franklin County, and sections 6, 7, and 8, Bloom Township, Fairfield County, East Columbus quadrangle.

Measured in the tributary of Walnut Creek which flows on the northeast side of Lithopolis. Base of section in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ of section 1, Madison Township, Franklin County, just west of the county line road. Top of section at the intersection of the stream and the east-west road in the SW$\frac{1}{4}$ of section 8, Bloom Township, Fairfield County.

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
RACCOON MEMBER

	Feet
8. Siltstone to very fine grained sandstone with interbedded shale. Siltstone to very fine grained sandstone, light olive gray (5 Y 6/1) to light bluish gray (5 B 7/1); weathers to various shades of olive and brown; massive, occurring in beds up to 2 feet in thickness, some tendency to weather thin bedded, slightly micaceous, hard, ledge-forming; current ripple marks occur 15 feet above base of unit; suggested current direction N. 75° W.; worm trails (?) on lower surfaces of massive beds; massive beds overlie shales with sharp contact. Shale, light olive gray (5 Y 6/1), soft, fissile, micaceous; scattered carbonaceous fragments; variable silt content; grades downward into the massive intervening beds through a transition zone consisting of soft, thin-bedded, argillaceous siltstone with abundant mica flakes and carbonaceous specks; thickness of thin-bedded portions ranges from 2 inches to 4 feet. Base of unit placed at lowest massive siltstone ledge; basal contact sharp.	80
7. Mudstone, medium gray (N5), iron-stained on weathered surface, very slightly silty, blocky, soft, slightly micaceous; basal contact sharp.	4.5

Kinderhook Series
Sunbury shale

	Feet
6. Shale, grayish black (N2), iron-stained on weathered surface, fissile; scattered lenses of medium gray (N5) shale up to 1 inch in width in uppermost few inches; base not seen.	28.0
5. Covered interval	2.5

Berea sandstone

	Feet
4. Sandstone, light brown (5 YR 5/6), iron-stained, very fine grained, medium-bedded, slightly micaceous; scattered accumulations of pyrite crystals; hard, ledge-forming, ripple marked; basal contact disconformable.	5.5

Bedford shale

	Feet
3. Mudstone, medium gray (N5); weathers to moderate yellowish brown (10 YR 5/4); blocky, silty, slightly micaceous; intermittently exposed; base covered; occasional hard, light gray (N7), lenticular siltstone layers up to 1 inch thick near base	20
2. Covered interval; thickness estimated from topographic contours.	40

DEVONIAN SYSTEM
Ohio shale

1. Shale, grayish black (N2), fissile; small exposure in stream bed; thickness not measured.

Elevation at base of Bedford shale 808 feet (aneroid barometer)

O. G. S. 12110

Stratigraphic section of Mississippian strata in section 10, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ of the section, in the abandoned Allegheny quarry.

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BYER MEMBER

	Feet
8. Sandstone, dusky yellow (5 Y 6/4), very fine grained, thin- to medium-bedded; more resistant than underlying Berne member; basal contact sharp	14.0

BERNE MEMBER

	Feet
7. Sandstone, very light gray (N8) to dark reddish brown (10 R 3/4), iron-stained; consists of very friable, poorly sorted, conglomeratic sandstone which intergrades with fine-grained sandstone; occasional lenses up to 2 inches thick of greenish gray (5 GY 6/1) shale; unit weathers rapidly to form a slight re-entrant in the quarry face; basal contact sharp	2.9
6. Sandstone, moderate yellowish brown (10 YR 5/4), fine-grained, thin-bedded; hydrous iron oxide bands and nodules; basal contact gradational.	3.0
5. Sandstone, moderate yellowish brown (10 YR 5/4) to dusky brown (5 YR 2/2), coarse-grained, ferruginous; hydrous iron oxide streaks; occurs in beds and lenses 3 to 4 inches thick, and is interbedded and intergradational with sandstone similar to that in unit 4; unit crossbedded; basal contact gradational	2.2

	Feet
4. Sandstone, moderate yellowish brown (10 YR 5/4), fine-grained, thin-bedded, micaceous, well-cemented; iron oxide bands and nodules; basal contact gradational.	2.5
3. Sandstone, light brown (5 YR 5/6), poorly sorted, fine- to coarse-grained; coarser grains tend to be subrounded; massive; light gray (N7) clay occurs in small lenses up to 1 inch in thickness; basal contact sharp.	1.3
2. Sandstone, moderate brown (5 YR 4/4), fine-grained, thin-bedded, micaceous; in upper 3 inches grades upward into moderate yellowish brown (10 YR 5/4), very thin bedded, micaceous siltstone; basal contact of unit sharp.	1.1
Kinderhook and Osage Series Cuyahoga formation BLACK HAND MEMBER	
1. Sandstone, yellowish gray (5 Y 7/2), iron-stained, fairly well sorted, medium-grained; grains subangular with abundant overgrowths; massive, friable, crossbedded; occasional small zones of honeycomb weathering on otherwise smooth quarry face; scattered nodules and bands of iron oxide; base not seen	30.0

Elevation at base of section 892 feet (aneroid barometer)

O. G. S. 12118

Stratigraphic section of Mississippian strata in section 33, Richland Township, Fairfield County, Thornville quadrangle.

Measured in the northern half of the SW¼ of the section in a steep gully on the west side of Rush Creek immediately north of the railroad cut which is located approximately three-quarters of a mile south of U. S. Route 22. Base of section is a small exposure at stream level on the east bank of Rush Creek about 150 yards downstream.

	Feet
MISSISSIPPIAN SYSTEM Osage Series Logan formation VINTON MEMBER	
12. Sandstone, moderate yellowish brown (10 YR 5/4), iron-stained, fine-grained, thin-bedded to massive, but most commonly medium-bedded; fine lamination in some beds; micaceous; interbedded in lower 5 feet with shale, light olive gray (5 Y 5/2), slightly silty, fissile, soft; fossiliferous zone 8.5 feet above base of unit contains brachiopods, bryozoans, crinoid columnals; base of unit sharp	19.0
11. Mudstone, moderate olive brown (5 Y 4/4) to light olive gray (5 Y 5/2), slightly silty, blocky, micaceous, soft, poorly exposed; basal contact sharp	9.0
10. Sandstone, medium gray (N5) to light olive gray (5 Y 6/1), very fine grained, very thin bedded to massive; massive beds are ledge forming; commonly shows fine lamination and some fine cross-lamination; micaceous; sparse brachiopods and crinoid columnals; occasional intercalations of soft shale 1/4 to 1/2 inch thick; basal contact of unit sharp.	20.5
9. Mudstone, medium gray (N5); variable silt content; blocky, soft, micaceous; sandstone of same lithologic type as unit 8 occurs 0.7 feet above the base of the unit in a layer 0.3 feet thick; basal contact gradational.	2.8
8. Sandstone, light bluish gray (5 B 6/1) to light olive gray (5 Y 5/2), very fine grained, thin-bedded, hard, micaceous; basal contact sharp	8.6
7. Siltstone, medium gray (N5) to light olive gray (5 Y 5/2), iron-stained, very thin bedded, slightly micaceous; sparse brachiopods and bryozoans; grades upward to soft, blocky mudstone in upper 3 feet; base of unit gradational . .	18.4
6. Mudstone, dark gray (N3), iron-stained on weathered surface; variable silt content; blocky, soft; basal contact gradational.	1.3
5. Siltstone, light bluish bray (5 B 7/1) to light olive gray (5 Y 5/2), thin-bedded, hard; basal contact sharp	0.8
4. Siltstone, medium gray (N5) to light olive gray (5 Y 5/2), thin-bedded, slightly micaceous; flat, discoid concretions up to 4 feet in diameter occur in layers 10.0 and 14.4 feet above the base of the unit.	15.0
3. Siltstone, medium gray (N5), iron-stained on weathered surface, thin-bedded to massive; fine laminations in part; micaceous; brachiopods and crinoid columnals occur near base and in restricted zones higher in unit; basal contact sharp	11.0
2. Siltstone, medium gray (N5) to light olive gray (5 Y 5/2), iron-stained on weathered surface, very thin bedded, finely laminated, slightly micaceous; occasional thin (1 to 2 inches) intercalations of soft, crumbly siltstones; clay-ironstone concretions generally scattered but occurring also in a layer 21.4 feet above the base of the unit; concretions are cylindrical, 1 to 2 inches in diameter and up to 5 inches in length; basal contact sharp	30.4
ALLENSVILLE MEMBER	
1. Sandstone, medium gray (N5) to brownish gray (5 YR 4/1), iron-stained, weathers to moderate yellowish brown (10 YR 5/4), coarse-grained, massive, friable; with irregular argillaceous to silty layers 1 to 2 inches thick; base covered; lower 8.4 feet covered except for a small ledge at stream level	20.0

Elevation at base of section 846 feet (aneroid barometer)

O. G. S. 12454

Stratigraphic section of Mississippian strata in section 28, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the NW¼ NW¼ NE¼ of the section, in an abandoned quarry located on the east wall of the Hocking Valley, three-quarters of a mile north of Clark Crossing.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
BYER MEMBER	
12. Sandstone, dusky yellow (5 Y 6/4), very fine grained, medium- to thick-bedded with beds up to 8 inches thick; occurs in layers up to 3 feet in thickness which are interbedded and intergradational with very thin bedded, silty, grayish orange (10 YR 7/4) mudstone ranging in thickness from a few inches to 3 feet; basal contact sharp.	8.0
BERNE MEMBER	
11. Sandstone, dark yellowish orange (10 YR 6/6), medium-grained, massive; with hydrous iron oxide bands	1.0
10. Shale, dusky yellow (5 Y 6/4), soft fissile, lenticular.	0.1
9. Sandstone, dark yellowish orange (10 YR 6/6), conglomeratic; pebbles up to 8 mm in diameter in a matrix of medium- to coarse-grained sandstone; not bedded, but pebbles roughly concentrated in layers parallel to top and bottom of unit; very friable; hydrous iron oxide bands up to 1 inch thick	2.3
8. Sandstone, yellowish gray (5 Y 7/2) to dark yellowish orange (10 YR 6/6), medium-grained, crossbedded; basal contact sharp and slightly undulatory	0.7
7. Shale, pale olive (10 Y 6/2), soft, fissile, somewhat silty, micaceous, lenticular	0.1
6. Sandstone, grayish orange (10 YR 7/4), medium-grained but varying locally to coarse-grained, massive, ferruginous; with thin hydrous iron oxide bands; base marked by a heavy hydrous iron oxide band 2 inches thick. . .	3.6
5. Sandstone, dark yellowish orange (10 YR 6/6), fine-grained, thin- to medium-bedded; hydrous iron oxide bands up to 3/4 inch in thickness; basal contact sharp	1.3
4. Siltstone, moderate yellowish brown (10 YR 5/4), iron-stained, crumbly, blocky.	0.3
3. Sandstone, moderate yellowish brown (10 YR 5/4), medium- to coarse-grained, massive; 2-inch zone of heavy hydrous iron oxide concentration at top	1.7
2. Mudstone, light olive gray (5 Y 5/2) to moderate yellowish brown (10 YR 5/4), soft, blocky; basal contact sharp	0.1
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), medium- to coarse-grained with local concentrations of very coarse sand, massive, crossbedded; a layer of very coarse grained, highly ferruginous sandstone comprises the uppermost 2 to 4 inches; base not seen.	27.0

Elevation at base of section 946 feet (Paulin altimeter)

O. G. S. 14546

Stratigraphic section of Mississippian strata in section 34, Clear Creek Township, Fairfield County, Circleville quadrangle.

Section measured in the NW¼ SW¼ of the section on the west bank of Salt Creek just north of Tarlton Cross Mound.

	Feet
MISSISSIPPIAN SYSTEM	
Kinderhook and Osage Series	
Cuyahoga formation	
RACCOON MEMBER	
1. Mudstone, medium dark gray (N4), slightly silty, micaceous, soft, with scattered clay ironstone concretions. Intercalated sandstone, moderate yellowish brown (10 YR 5/4), fine- to medium-grained, micaceous; carbonaceous fragments on bedding surfaces; flow casts common; scattered clay galls; beds range in thickness from 1/2 to 3 inches and occur from 3 inches to 2 feet apart.	52

Elevation at base of section 872 feet (Paulin altimeter)

O. G. S. 14547

Stratigraphic section of Mississippian strata in section 28, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the SE¼ SW¼ of the section in a road cut on the west side of the highway approximately one-half mile north of the Blue Valley road.

	Feet
MISSISSIPPIAN SYSTEM	
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
4. Sandstone, light gray (N7) to moderate yellowish brown (10 YR 5/4), coarse-grained with occasional pebbly zones, very friable, massive, irregularly iron stained; occasional hydrous iron oxide bands.	51.6
3. Covered interval	2.7
CUYAHOGA FORMATION, UNDIFFERENTIATED	
2. Sandstone, light gray (N7) to dark yellowish orange (10 YR 6/6), irregularly iron stained,	

Feet

fine-grained, medium-bedded; contorted hydrous iron oxide bands, micaceous; clay galls up to 1/2 inch in diameter and very thin argillaceous layers occur alined parallel to bedding; basal contact gradational. 26.0

RACCOON MEMBER

1. Mudstone and siltstone interbedded; medium gray (N5), micaceous, slightly silty mudstone alternates with light olive gray (5 Y 6/1), hard siltstone; beds range from 1/4 to 3 inches in thickness; siltstone increases in abundance upward in upper 25 feet of unit; base not seen. 67.0

Elevation at base of section 787 feet (Paulin altimeter)

O. G. S. 14548

Stratigraphic section of Mississippian strata in section 17, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ of the section in a road cut west of the highway and a fifth of a mile north of Stump Hollow road.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
RACCOON MEMBER

2. Mudstone, pale yellowish brown (10 YR 6/2), iron-stained, silty, blocky, crumbly, micaceous; base not seen. 15.0

BLACK HAND MEMBER

1. Sandstone, pale yellowish orange (10 YR 8/6) to moderate reddish brown (10 R 4/6), poorly sorted, fine- to coarse-grained; some irregular hydrous iron oxide bands; massive; can be traced laterally along road cut into thin- to medium-bedded sandstone, base not seen 25.5

Elevation at base of section 803 feet (Paulin altimeter)

O. G. S. 14549

Stratigraphic section of Mississippian strata in section 15, Good Hope Township, Hocking County, Lancaster quadrangle.

Measured in the NW$\frac{1}{4}$ of the section in a road cut on the west side of the highway just south of the Fairfield-Hocking County line.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

3. Sandstone, grayish orange (10 YR 7/4), medium- to coarse-grained; grains subangular; friable, massive; base inaccessible on road cut. 68

Feet

CUYAHOGA FORMATION, UNSUBDIVIDED

2. Thin interbedded mudstone and siltstone (Raccoon member) passing upward into fine-grained sandstone (Cuyahoga formation, undifferentiated); unit inaccessible on road cut; thickness based on float 112

BLACK HAND MEMBER

1. Sandstone, grayish orange (10 YR 7/4) to moderate brown (5 YR 4/4), irregularly iron-stained, poorly sorted, fine- to coarse-grained, predominantly medium grained, slightly friable, massive, crossbedded; occasional hydrous iron oxide bands; occurs at the base of the section as a lens approximately 500 feet in width; wedges out into the mudstones and siltstones of unit 2, with which it is in sharp contact 0-8.0

Elevation at base of section 765 feet (Paulin altimeter)

O. G. S. 14550

Stratigraphic section of Mississippian strata in section 10, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ of the section in a road cut half a mile north of the 761-foot road corner and in the ravine immediately north of the road cut.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation

5. Abundant fragments of soft, yellow, very fine grained sandstone in the soil to the hilltop.

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

4. Sandstone, very light gray (N8) to grayish brown (5 YR 3/2), coarse-grained, locally conglomeratic, locally crossbedded, massive, cliff-forming; shelter caves at base; basal contact seems sharp because of abrupt break in slope and presence of small shelter caves at the base of unit. 60.0

CUYAHOGA FORMATION, UNDIFFERENTIATED

3. Sandstone, pale yellowish brown (10 YR 6/2) to light brown (5 YR 5/6), fine-grained, micaceous, thin- to medium-bedded, hard, slope-forming, intermittently exposed; base not seen. 53.5

2. Covered interval. 16.0

RACCOON MEMBER

1. Mudstone, dark yellowish brown (10 YR 4/2), soft, slightly silty, slightly micaceous, blocky; base not seen 4.5

Elevation at base of section 769 feet (Paulin altimeter)

O. G. S. 14551

Stratigraphic section of Mississippian strata in section 29, Pleasant Township, Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ of the section in an excavation located a quarter of a mile west of the north-south road and just north of the long lane.

	Feet
MISSISSIPPIAN SYSTEM	
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
2. Sandstone, dark yellowish orange (10 YR 6/6), to moderate reddish brown (10 R 4/6), medium- to coarse-grained; grains subangular; quartz overgrowths common; hydrous iron oxide bands; massive	1.5
CUYAHOGA FORMATION, UNDIFFERENTIATED	
1. Sandstone, grayish orange (10 YR 7/4), fine-grained, ferruginous, micaceous, thin- to medium-bedded, soft	35.5

Elevation at base of section 928 feet (Paulin altimeter)

O. G. S. 14552

Stratigraphic section of Mississippian strata in section 9, Berne Township, Fairfield County, Lancaster quadrangle.

Measured on the southern border of section 9 along the east-west road from the valley of Pleasant Run in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ of the section to the lane at the hilltop in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ of the section.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
ALLENSVILLE MEMBER	
6. Sandstone, very pale orange (10 YR 8/2) to dark yellowish orange (10 YR 6/6), poorly sorted, fine- to coarse-grained; heavy hydrous iron oxide bands; occurs as float to hilltop	11
BYER MEMBER	
5. Sandstone, dark yellowish orange (10 YR 6/6), iron-stained, fine-grained, soft, thin-bedded, finely laminated; upper portion occurs as float	32
4. Covered interval; no evidence of Berne member	34
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
3. Sandstone, moderate yellowish brown (10 YR 5/4) to dark yellowish orange (10 YR 6/6), medium- to coarse-grained, massive, cross-bedded, cliff-forming; occasional hydrous iron oxide bands	47
2. Covered interval	7
CUYAHOGA FORMATION, UNDIFFERENTIATED	
1. Sandstone, moderate yellowish brown (10 YR 5/4), fine-grained, thin- to medium-bedded, soft, slightly micaceous, poorly exposed	33

Elevation at base of section 863 feet (Paulin altimeter)

O. G. S. 14553

Stratigraphic section of Mississippian strata in sections 22 and 23, Berne Township, Fairfield County, Lancaster quadrangle.

Measured along the road from the NW$\frac{1}{4}$ SW$\frac{1}{4}$ of section 23 to the hilltop immediately northeast of the 1059-foot road corner in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ of section 22.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
7. Siltstone, moderate yellowish brown (10 YR 5/4), soft, thin- to medium-bedded, micaceous, intermittently exposed	99
6. Mudstone, grayish orange (10 YR 7/4), iron-stained, blocky, soft, silty	8.0
5. Covered interval	1.0
ALLENSVILLE MEMBER	
4. Sandstone, moderate yellowish brown (10 YR 5/4) to dark yellowish orange (10 YR 6/6), iron-stained, coarse-grained, friable, thin- to medium-bedded; quartz overgrowths common; poorly exposed; thickness based on float.	14
BYER MEMBER	
3. Sandstone, moderate yellowish brown (10 YR 5/4) to light olive brown (5 Y 5/6), very fine grained with scattered grains or layers one grain thick of coarse-grained sand to granules; thin- to medium-bedded, soft; a fossiliferous zone with brachiopods and abundant crinoid columnals occurs 11 feet above the base of the unit	51
2. Covered interval; no evidence of Berne member	24
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
1. Sandstone, light brown (5 YR 5/6), medium- to coarse-grained; quartz overgrowths common; massive, slightly friable	8.0

Elevation at base of section 874 feet (Paulin altimeter)

O. G. S. 14554

Stratigraphic section of Mississippian strata in section 2, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured along the road which rises to the west from the house located on the line between sections 1 and 2.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
ALLENSVILLE MEMBER

4. Sandstone, dark yellowish orange (10 YR 6/6), very coarse grained; subangular sand and granules in a matrix of ferruginous silt or clay; irregular hydrous iron oxide bands, beds 4 to 6 inches thick. 2.0

BYER MEMBER

3. Siltstone, grayish orange (10 YR 7/4); fine lamination accentuated by iron staining; thin- to medium-bedded, hard, micaceous; in upper portion consists of very fine grained sandstone with occasional rounded grains of medium- to coarse-grained sand; poorly exposed. 48

BERNE MEMBER

2. Covered interval with fragments of sandstone, dark yellowish orange (10 YR 6/6); composed of coarse-grained sand to pebbles up to 1/8 inch in diameter in a matrix of ferruginous silt or clay; abundant quartz overgrowths. 11.0

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

1. Sandstone, medium light gray (N6), coarse-grained, massive; abundant quartz overgrowths; intermittently exposed down the valley to the northeast; thickness not measured.

Elevation at base of Berne member 849 feet (Paulin altimeter)

O. G. S. 14555

Stratigraphic section of Mississippian and Pennsylvanian strata in sections 13 and 14, Berne Township, Fairfield County, Lancaster quadrangle.

Measured along the northwest-southeast road from the bend in the road by the house in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 14 to the top of the hill in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ of section 13.

Feet

PENNSYLVANIAN SYSTEM
Pottsville Group

9. Poorly exposed coarse-grained sandstone, soft gray clay, and micaceous silty shale. . . 58

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

8. Siltstone to very fine grained sandstone, yellowish gray (5 Y 8/1) to light brown (5 YR 5/6), slightly micaceous, thin- to medium-bedded; lower 15 feet of unit contains abundant brachiopod valves and scattered crinoid columnals; uppermost few feet appear weathered, bleached, with heavy iron staining along joint surfaces. 92

7. Covered interval 24

ALLENSVILLE MEMBER

6. Sandstone, dark yellowish orange (10 YR 6/6); coarse-grained to very coarse grained subangular sand in a matrix of ferruginous silt and very fine grained sand; varies from fine-grained sandstone with scattered coarser grains to coarse-grained to very coarse grained sandstone with a small amount of interstitial fines; occasional hydrous iron oxide bands; medium- to thick-bedded with beds up to 1 foot thick; varies from very hard to very friable with the more resistant beds forming ledges 8.0

5. Siltstone, grayish orange (10 YR 7/4); weathered surfaces mottled dusky yellowish brown (10 YR 2/2); slightly micaceous, soft, medium-bedded. 2.0

4. Covered interval 7.5

3. Mudstone, dark yellowish orange (10 YR 6/6); mottled dusky yellowish brown (10 YR 2/2) on weathered surfaces; silty, soft, blocky; scattered grains of coarse, rounded sand. 2.0

2. Sandstone, moderate yellowish brown (10 YR 5/4) to dark yellowish brown (10 YR 4/2); coarse-grained, subrounded sand with interstitial silt and clay; very friable, ferruginous; occasional ferruginous bands. 0.5

BYER MEMBER

1. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), very fine grained, thin- to medium-bedded, micaceous; some iron stain; occasional crinoid columnals . 16.0

Elevation at base of section 900 feet (Paulin altimeter)

O. G. S. 14556

Stratigraphic section of Mississippian and Pennsylvanian strata in section 31, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured along the east-west road in the southern half of the section from a point a fifth of a mile west of the 807-foot road corner to the hilltop located three-fifths of a mile west of the 807-foot road corner.

	Feet
PENNSYLVANIAN SYSTEM	
Pottsville Group	
8. Sandstone, light brown (5 YR 5/6) to dark yellowish orange (10 YR 6/6), iron-stained, medium-grained, massive, hard.	1.5
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
7. Sandstone, light olive brown (5 Y 5/6), very fine grained, thin-bedded soft, intermittently exposed; extensive leaching of iron indicated in the upper 15 feet with hydrous iron oxide either absent or present only as small specks or very thin concentric bands; uppermost 2 to 3 feet consists largely of soft clay.	58
6. Covered interval.	85
5. Siltstone, pale yellowish brown (10 YR 6/2) to grayish orange (10 YR 7/4), iron-stained, slightly micaceous, hard, thin- to medium-bedded	18.0
4. Covered interval.	17.0
ALLENSVILLE MEMBER	
3. Sandstone, moderate yellowish brown (10 YR 5/4) to dark yellowish orange (10 YR 6/6); varies from very fine grained sandstone with scattered grains of coarse sand to coarse-grained to very coarse grained sandstone consisting of subangular grains with interstitial ferruginous silt and clay; very poorly exposed	12.0
BYER MEMBER	
2. Sandstone, grayish orange (10 YR 7/4), very fine grained with scattered grains of medium and coarse sand, medium-bedded, soft.	6.5
1. Siltstone, yellowish gray (5 Y 7/2) to pale yellowish brown (10 YR 6/2), slightly iron stained, thin- to medium-bedded, hard, slightly micaceous; scattered crinoid columnals.	18.0

Elevation at base of section 821 feet (Paulin altimeter)

O. G. S. 14558

Stratigraphic section of Mississippian strata in sections 11, 12, and 14, Madison Township, Fairfield County, Lancaster quadrangle.

Measured along road running north and east from Revenge. Base of section located in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ of section 14 approximately a tenth of a mile north of Clear Creek. Top of section located in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 12 approximately a tenth of a mile west of the 1182-foot road corner.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
ALLENSVILLE MEMBER	
8. Sandstone, dark yellowish orange (10 YR 6/6), heavily iron stained; coarse-grained to very coarse grained subangular sand in a matrix of fine-grained sandstone; hard, thin- to medium-bedded; basal contact sharp.	1.0
BYER MEMBER	
7. Sandstone, grayish orange (10 YR 7/4), irregularly iron stained, very fine grained, thin- to medium-bedded, soft, slightly micaceous; scattered crinoid columnals; heavy hydrous iron oxide concentrations on bedding surfaces; basal 7 inches thoroughly impregnated with hydrous iron oxide so as to form a hard, heavy, dark rock; base not seen	23
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
6. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), poorly sorted; consists of subangular medium-grained to very coarse grained sand with a small amount of fine-grained sand; scattered pebbles up to 1 inch but usually less than 1/4 inch in diameter; pebbles particularly abundant in the upper few feet; massive, but with a slight tendency toward slabbiness; friable; occurs as ledges along the road bank, occasionally crossbedded; in the lower 17 feet varies laterally to moderate reddish brown (10 R 4/6) sandstone with irregular hydrous iron oxide bands up to half an inch in thickness; base not seen	72
5. Sandstone, grayish orange (10 YR 7/4) to pale reddish brown (10 R 5/4); consists of medium- to coarse-grained subangular sand; occasionally pebbly with pebbles 1/4 inch in diameter or smaller; scattered clay galls up to 1 inch in diameter; occasional hydrous iron oxide bands up to 1/2 inch in thickness; extremely soft and friable; in large part totally unconsolidated, but occasional massive ledges have been freshly exposed in the ditch; very poorly exposed; exact positions of base and top as well as vertical continuity of lithologic character uncertain.	51
4. Covered interval.	52
3. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), locally dark reddish brown (10 R 3/4); varies from fine- to medium-grained sandstone to a poorly sorted sandstone consisting of subangular grains of fine to very coarse sand; locally conglomeratic, particularly in upper portion, with pebbles generally 1/4 inch or smaller but not uncommonly as large as 3/4 inch in diameter; frequent 1- to 6-inch layers of soft, sandy, yellowish gray (5 Y 7/2) clay, abundant clay galls up to 2 inches in diameter; bedding not well shown, massive at least in part; irregular hydrous iron oxide bands up to 1 inch in thickness; soft, badly weathered, poorly exposed.	58

		Feet
2.	Covered interval.	89
1.	Sandstone, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4), iron-stained, medium- to coarse-grained, massive; hydrous iron oxide bands and clay galls abundant; removal of clay galls by weathering leaves almond-shaped cavities up to 2-1/2 inches long; a 1-inch layer of very light gray (N8), sandy, plastic clay occurs in sharp contact with the sandstone 7 feet above the base of the unit. . .	14.0

Elevation at base of section 838 feet (Paulin altimeter)

O. G. S. 14559

Stratigraphic section of Mississippian strata in section 9, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ of the section in the abandoned Sharp quarry on the hillside due west of the cemetery.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BYER MEMBER

4.	Siltstone, pale yellowish brown (10 YR 6/2), iron-stained, micaceous; resistant medium-bedded layers interbedded and intergradational with relatively soft thin-bedded layers; basal contact sharp.	8.0

BERNE MEMBER

3.	Sandstone, moderate yellowish brown (10 YR 5/4), coarse-grained, pebbly; pebbles average 1/8 inch in diameter; argillaceous, soft, friable, massive, very poorly exposed; forms the most rapidly retreating unit on the quarry face, where it is not accessible	3.7
2.	Mudstone, very dark red (5 R 2/6), soft, brittle; fine- to medium-grained sand occurs in thin layers several grains thick	0.3

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

1.	Sandstone, moderate yellowish brown (10 YR 5/4), iron-stained, medium- to coarse-grained, locally pebbly with pebbles up to 1 inch but generally smaller than 1/4 inch in diameter, massive, slightly friable; occasional lenses up to 3 inches thick and 6 feet wide of soft, blocky mudstone, which weathers to gray, plastic clay.	45.0

Elevation at base of section 920 feet (Paulin altimeter)

O. G. S. 14560

Stratigraphic section of Mississippian strata in section 12, Madison Township, Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ of the section along the east-west road from the first road intersection southeast of the 1182-foot road corner up the hill toward the east boundary of the township.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BYER MEMBER

5. Sandstone, dark yellowish orange (10 YR 6/6), very fine grained, soft; basal 3 inches heavily impregnated with hydrous iron oxide; thickness not measured.

BERNE MEMBER

4.	Sandstone, dark yellowish orange (10 YR 6/6), medium- to coarse-grained with rare pebbles up to 1/8 inch in diameter, argillaceous, ferruginous, massive, friable; basal contact gradational.	1.0
3.	Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), conglomeratic; pebbles up to 3/4 inch but generally near 1/4 inch in diameter in a matrix of coarse-grained, argillaceous, ferruginous, friable sandstone with abundant paper-thin clay lenses up to 2 inches in diameter	11.0
2.	Clay, pale olive (10 Y 6/2), plastic, discontinuous; basal contact sharp and slightly undulatory.	0.1

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

1.	Sandstone, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4), coarse-grained, locally pebbly with pebbles up to 1/2 inch but most commonly from 1/8 to 1/4 inch in diameter, friable, massive; base not seen.	24.0

Elevation at base of section 1112 feet (Paulin altimeter)

O. G. S. 14562

Stratigraphic section of Mississippian strata in sections 25 and 36, Hocking Township, Fairfield County, Lancaster quadrangle.

Measured in the NE$\frac{1}{4}$ of section 36 along the northwest-southeast road from a point located approximately a quarter of a mile northwest of its intersection with the township line to the corner in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of section 36; thence west along the ditch and road bank on the north side of the east-west road to the hilltop just east of the 1124-foot road corner.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
ALLENSVILLE MEMBER	
11. Abundant Allensville float to top of hill.	
BYER MEMBER	
10. Sandstone, dark yellowish orange (10 YR 6/6), very fine grained; occasional very thin layers of fine- to medium-grained sand; thin-bedded, soft; scattered crinoid columnals; base covered	20.0
9. Covered interval	2.1
BERNE MEMBER	
8. Sandstone, light brown (5 YR 5/6), poorly sorted; consists of fine- to coarse-grained subangular sand; massive, slightly friable; hydrous iron oxide bands; base covered	1.2
7. Covered interval	0.6
6. Conglomerate, dark yellowish orange (10 YR 6/6), consists of well-rounded quartz pebbles ranging from 1/8 to 1 inch in diameter with an average diameter of 1/4 to 1/2 inch in a matrix of medium-grained sand; pebbles show frequent secondary crystallization; heavy hydrous iron oxide bands; basal contact sharp	1.0
5. Sandstone, dark yellowish orange (10 YR 6/6), well-sorted, fine-grained; grains subangular; massive, slightly friable; hydrous iron oxide bands; base covered	2.5
4. Covered interval; contains Berne float: rounded pebbles up to 1/4 inch in diameter in a matrix of poorly sorted, fine- to coarse-grained sandstone	22.5
3. Clay, light gray (N7), somewhat iron-stained, plastic, sandy, basal contact sharp	1.0
2. Sandstone, light brown (5 YR 5/6), coarse-grained; grains subangular; quartz overgrowths common; massive, very friable; basal contact sharp	1.8
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
1. Sandstone, dark yellowish orange (10 YR 6/6) to dark yellowish brown (10 YR 4/2); consists of subangular to subrounded medium- to coarse-grained sand with occasional pebbly layers; pebbles up to 1/4 inch in diameter; massive; honeycomb weathering; variable friability; apparent dip 9°, N. 25° E.; beds horizontal in upper portion; base covered	103

Elevation at base of section 980 feet (Paulin altimeter)

O. G. S. 14563

Stratigraphic section of Mississippian strata in section 23, Madison Township, Fairfield County, Lancaster quadrangle.

Measured along the road running roughly north-south through the section from a point just south of the boundary between sections 14 and 23 to the hilltop at the road intersection in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 23.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
BYER MEMBER	
4. Sandstone, dark yellowish orange (10 YR 6/6), very fine grained, thin- to medium-bedded, soft; scattered crinoid columnals; heavy hydrous iron oxide concentrations near base; base covered by slumping	14.0
BERNE MEMBER	
3. Sandstone, dark yellowish orange (10 YR 6/6); consists of subangular medium- and coarse-grained sand with occasional pebbles up to 1/4 inch in diameter; occurs as almost entirely unconsolidated sand; basal contact sharp	5.5
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
2. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4); consists of poorly sorted, subangular sand grains ranging in size from fine to coarse grained, but predominantly medium grained; occasional pebbly zones containing pebbles up to 1/4 inch in diameter; quartz overgrowths common, massive, slightly friable, cross-bedded; clay galls in lower portion; intermittently exposed; basal contact gradational	125
1. Sandstone, dark yellowish orange (10 YR 6/6) to pale reddish brown (10 R 5/4), fine- to medium-grained with occasional pebbly portions, thin- to medium-bedded; upper 2 feet appears to pass laterally into massive sandstone; hydrous iron oxide bands up to 1/4 inch in thickness; clay galls abundant; poorly exposed; base not seen	10.0

Elevation at base of section 1035 feet (Paulin altimeter)

O. G. S. 14564

Stratigraphic section of Mississippian strata in sections 22 and 27, Berne Township, Fairfield County, Lancaster quadrangle.

Measured along road from a point located approximately a tenth of a mile south of the right-angle bend in the road in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 27 to a point just north of the intersection of the road and the boundary between sections 22 and 27 in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ of section 22.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
11. Siltstone, dark yellowish orange (10 YR 6/6), thin- to medium-bedded, finely laminated, hard; base not seen; Vinton float on hillside above contains scattered productids and crinoid columnals.	1.6
10. Covered interval.	8.8
9. Siltstone, dark yellowish orange (10 YR 6/6), thin- to medium-bedded, finely laminated, hard, base not seen	0.6
8. Covered interval.	24.0
ALLENSVILLE MEMBER	
7. Sandstone, dark yellowish orange (10 YR 6/6), fine- to coarse-grained; grains subangular; medium-bedded, slightly friable; hydrous iron oxide bands; basal contact sharp; generalized description based on very poor exposure.	12.4
BYER MEMBER	
6. Siltstone, dusky yellow (5 Y 6/4), thin-bedded, crumbly, intermittently exposed; abundant crinoid columnals in some horizons; basal contact sharp	60
BERNE MEMBER	
5. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), medium- to coarse-grained; grains subangular; conglomeratic except for upper 3 inches; pebbles average 1/8 inch in diameter; massive; occasional hydrous iron oxide bands; base covered.	1.4
4. Covered interval.	2.0
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
3. Sandstone, dark yellowish orange (10 YR 6/6); consists of well-sorted, subangular to subrounded, medium-grained quartz sand; very coarse grained in upper 3 inches; quartz overgrowths common; massive, slightly friable; shelter cave at base in ravine just east of road.	20
CUYAHOGA FORMATION, UNDIFFERENTIATED	
2. Covered interval; at top of interval a sandstone similar to that of unit 1 underlies the shelter floor	28
1. Sandstone, light brown (5 YR 5/6) to dark yellowish orange (10 YR 6/6), somewhat iron-stained, very fine grained, thin- to medium-bedded, hard; base covered	7.0

Elevation at base of section 833 feet (Paulin altimeter)

O. G. S. 14565

Stratigraphic section of Mississippian strata in section 1, Madison Township, Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ of the section from a point in the lane about a tenth of a mile from Ridge Road to a point on Ridge Road about a tenth of a mile north of its intersection with the lane.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
BYER MEMBER	
6. Siltstone, dark yellowish orange (10 YR 6/6), thin-bedded, hard; bedding surfaces impregnated with hydrous iron oxide; badly weathered and slumped; base covered.	2.0
5. Covered interval.	4.6
BERNE MEMBER	
4. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4); consists of coarse-grained subangular sand with interstitial clay and silt; medium- to thick-bedded; highly ferruginous; friable except in areas of heaviest hydrous iron oxide accumulation; base covered	1.3
3. Covered interval.	15.0
2. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), very poorly sorted, fine-grained to very coarse grained; grains subangular; conglomeratic in lower 2 inches with pebbles up to 1/2 inch in diameter, but usually ranging from 1/8 to 1/4 inch in diameter; ferruginous; basal contact sharp.	0.7
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
1. Sandstone, dark yellowish orange (10 YR 6/6), medium- to coarse-grained; grains subangular; scattered rounded pebbles up to 1/4 inch in diameter; massive, friable; intermittently exposed on down the lane; thickness not measured	

Elevation at base of Berne member 1128 feet (Paulin altimeter)

O. G. S. 14566

Stratigraphic section of Mississippian strata in section 1, Madison Township, Fairfield County, Lancaster quadrangle.

Measured in the NE$\frac{1}{4}$ of the section along Ridge Road from the small gully which intersects Ridge Road 0.15 mile southwest of the 1170-foot road corner to the hilltop located 0.2 mile southwest of the 1170-foot road corner.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BYER MEMBER

4. Siltstone, grayish orange (10 YR 7/4), thin- to medium-bedded, finely laminated, slightly micaceous; hydrous iron oxide heavily concentrated in lower 2 inches; basal contact sharp. 9.6

BERNE MEMBER

3. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted, fine- to coarse-grained; grains subangular; overgrowths common; pebbles up to 1/4 inch in diameter near base; massive; heavy hydrous iron oxide bands; friable; basal contact sharp 1.3

2. Sandstone, moderate yellowish brown (10 YR 5/4), conglomeratic; consists of subrounded pebbles up to 3/4 inch in diameter but averaging 1/4 inch in diameter in a matrix of subangular, medium- to coarse-grained sand; friable except where hydrous iron oxide is heavily concentrated; sharp basal contact due only to the abrupt appearance of abundant pebbles 0.9

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4); consists of subangular medium- to coarse-grained sand with a small amount of fine-grained sand; occasional pebbles up to 1/2 inch in diameter; average diameter is 1/8 inch; massive, friable; base not seen. 2.0

Elevation at base of section 1145 feet (Paulin altimeter)

O. G. S. 14567

Stratigraphic section of Mississippian strata in section 31, Pleasant Township, Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ of the section on the southwest face of Mt. Pleasant from Fair Avenue to the top of Mt. Pleasant.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BERNE MEMBER

7. Sandstone, light brown (5 YR 5/6), poorly sorted; consists of medium- to coarse-grained sand with some fine-grained and very coarse grained sand; abundant granules and pebbles up to 1/4 inch in diameter; very friable; tends to become buried in its own debris; basal contact sharp. 1.0

Feet

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

6. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), medium- to coarse-grained; grains subangular; scattered granules and pebbles up to 1 inch in diameter, but generally 1/8 inch or smaller; quartz overgrowths common; massive, cross-bedded, slightly friable, cliff-forming; honeycomb weathering; dips measured near top of unit less than 1°; basal contact gradational but marked by a shallow re-entrant which can be followed across the cliff face; contact sharp above the lenticular thin-bedded sandstone of unit 5. 36

5. Sandstone, grayish orange (10 YR 7/4); varies from medium-grained sandstone to poorly sorted medium- to coarse-grained sandstone; grains subangular; a prominent scour near the base is overlain by pebbly sandstone which grades upward into the overlying sandstone; pebbles up to 1/4 inch in diameter; interference ripples excellently preserved in a hard layer of hydrous iron oxide 14 feet above the base; a lens of thin- to medium-bedded sandstone with hydrous iron oxide bands occurs at the top of the unit and attains a maximum thickness of 2 feet; massive, hard, cliff-forming; occasional honeycomb weathering; dip varies from 3° N., 20° E. to 6°, N. 65° E.; basal contact gradational. 22

4. Sandstone, moderate reddish brown (10 R 4/6) to dark yellowish orange (10 YR 6/6); varies from fine-grained sandstone to medium- to coarse-grained sandstone; occasionally pebbly; pebbles less than 1/4 inch in diameter; massive, but with some poorly formed thin bedding, locally crossbedded, friable; occasional hydrous iron oxide bands and thin clay layers; scattered clay galls; basal contact gradational 14

3. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), medium-grained to very coarse grained; grains subangular; scattered granules and pebbles up to 1/4 inch in diameter; scattered clay galls up to 1 inch in diameter; massive, somewhat friable; occurs as an unbroken, steep, smooth ledge; base covered 76

2. Sandstone, pale yellowish brown (10 YR 6/2) to pale reddish brown (10 R 5/4), medium-grained; grains subangular; massive, cross-bedded, friable, ledge-forming; basal contact gradational 14

1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate reddish brown (10 R 4/6), fine- to medium-grained; grains subangular; slightly micaceous, very soft and friable, poorly exposed; scattered clay galls up to 1 inch in diameter; base not seen; upper 35 feet largely covered, but float and sparse, poor exposures indicate a tendency toward thin bedding. 60

Elevation at base of section 864 feet (Paulin altimeter)

O. G. S. 14568

Stratigraphic section of Mississippian strata in section 4, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ of the section on the east side of the hill.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

2. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), medium- to coarse-grained; grains subangular to subrounded; quartz overgrowths common; friable, massive, crossbedded; heavy hydrous iron oxide deposit on bedding surface; clay gall cavities up to 2 inches in diameter; slumped; base covered. 10.0

CUYAHOGA FORMATION, UNSUBDIVIDED

1. Siltstone and shale interbedded (Raccoon member); fine-grained sandstone in upper portion (Cuyahoga formation, undifferentiated).
Siltstone, dusky yellow (5 Y 6/4), iron-stained, thin- to medium-bedded, micaceous, hard; occurs as resistant ledges ranging in thickness from 8 inches to several feet.
Shale is moderate olive brown (5 Y 4/4), soft, silty, fissile to blocky; occurs in layers ranging in thickness from 1 to 4 inches.
Sandstone in upper portion is moderate yellowish brown (10 YR 5/4), fine grained, micaceous, medium bedded; brachiopods and crinoid columnals abundant on some bedding surfaces 43.0

Elevation at base of section 835 feet (Paulin altimeter)

O. G. S. 14569

Stratigraphic section of Mississippian strata in section 35, Pleasant Township, Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ of the section along the east-west road where it climbs the west valley wall of the stream which flows through the SE$\frac{1}{4}$ of the section.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
ALLENSVILLE MEMBER

2. Sandstone, moderate yellowish brown (10 YR 5/4), irregularly iron stained, poorly sorted, fine- to medium-grained; grains subangular; quartz overgrowths common; thin- to medium-bedded; occasional hydrous iron oxide bands; hard; rare brachiopods; basal contact sharp 15.0

BYER MEMBER

1. Siltstone, grayish orange (10 YR 7/4), somewhat iron-stained; thin- to medium-bedded, soft; scattered grains of fine to medium sand; occasional quartz overgrowths; scattered brachiopods and crinoid columnals; basal contact covered. 8.7

Elevation at base of section 891 feet (Paulin altimeter)

O. G. S. 14570

Stratigraphic section of Mississippian strata in section 33, Pleasant Township, Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ of the section along the Wheeling Road where it climbs the west valley wall of Pleasant Run.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
ALLENSVILLE MEMBER

15. Covered; float consists of poorly sorted, medium-grained to very coarse grained, ferruginous sandstone with scattered pebbles up to 1/8 inch in diameter.

BYER MEMBER

14. Siltstone, moderate yellowish brown (10 YR 5/4); occasional grains of subrounded, medium-grained sand; thin- to medium-bedded, soft; local hydrous iron oxide concentrations; base covered. 0.5

13. Covered interval 31.0

12. Siltstone to fine-grained sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), sand subangular, commonly with overgrowths; thin-bedded, finely laminated, soft; basal contact sharp 0.5

BERNE MEMBER

11. Sandstone, light brown (5 YR 5/6) to dark yellowish orange (10 YR 6/6), poorly sorted, fine- to medium-grained; grains subangular; overgrowths common; thin- to medium-bedded; thin hydrous iron oxide bands; basal contact sharp. 6.1

Kinderhook and Osage Series
Cuyahoga formation, unsubdivided

10. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), medium-grained, with interstitial fine-grained sand and silt; grains subrounded; quartz overgrowths common; massive, slightly friable, ledge-forming; basal contact sharp 4.3

9. Sandstone, dark yellowish orange (10 YR 6/6), fine-grained with scattered grains of medium sand; grains subangular; thin- to medium-bedded; friable; basal contact sharp. 1.3

8. Mudstone, grayish olive (10 Y 4/2), silty, soft, blocky, micaceous; basal contact sharp . . 1.0

7. Siltstone to very fine grained sandstone, moderate olive brown (5 Y 4/4), micaceous,

	Feet
medium-bedded, fairly hard; basal contact sharp	1.1
6. Mudstone, light olive gray (5 Y 5/2), slightly silty, blocky, micaceous, soft; base not seen	0.8
5. Covered interval	2.0
4. Siltstone, dark yellowish orange (10 YR 6/6); scattered subrounded grains of fine- to medium-grained sand; thin- to medium-bedded; basal contact sharp	2.2
3. Sandstone, light brown (5 YR 5/6), poorly sorted, very fine grained to medium-grained; grains subangular to subrounded; friable, very soft; bedding, if any, obscured by weathering; basal contact sharp	2.0
2. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6); consists of subangular medium- to coarse-grained sand in a matrix of fine-grained ferruginous sand; quartz overgrowths common on coarser grains; massive, hard, ledge-forming; basal contact sharp	4.2
1. Clay, light gray (N7), iron-stained, silty to sandy, plastic; base covered	0.5

Elevation at base of section 883 feet (Paulin altimeter)

O. G. S. 14571

Stratigraphic section of Mississippian strata in section 30, Madison Township, Fairfield County, and section 31, Perry Township, Hocking County, Lancaster quadrangle.

Measured in the $SW\frac{1}{4}$ $SE\frac{1}{4}$ of section 30 along the northeast-southwest road to its intersection with the Hocking County line; thence to the hilltop located immediately to the southeast in the $NW\frac{1}{4}$ $NE\frac{1}{4}$ of section 31.

	Feet
MISSISSIPPIAN SYSTEM	
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
3. Sandstone, grayish orange (10 YR 7/4), poorly sorted, fine- to coarse-grained; predominant grain size is medium; grains subangular to subrounded; quartz overgrowths common; occasional pebbles up to 1/8 inch in diameter; friable; occurs as massive blocks strewn on hilltop.	
2. Covered interval	19.5
CUYAHOGA FORMATION, UNDIFFERENTIATED	
1. Sandstone, dark yellowish orange (10 YR 6/6) to pale yellowish brown (10 YR 6/2), fine-grained, thin- to medium-bedded, micaceous, slightly friable; abundant weathered feldspar; base covered	22.0

Elevation at base of section 1115 feet (Paulin altimeter)

O. G. S. 14572

Stratigraphic section of Mississippian strata in section 12, Madison Township, Franklin County, section 13, Madison Township, Pickaway County, and sections 18 and 19, Bloom Township, Fairfield County, East Columbus quadrangle.

Measured along Big Run from the $NW\frac{1}{4}$ $SE\frac{1}{4}$ of section 12, Madison Township, Franklin County, to the $SE\frac{1}{4}$ $SE\frac{1}{4}$ $SE\frac{1}{4}$ of section 18, Bloom Township, Fairfield County, in the tributary of Big Run which flows north of the 985-foot road corner.

	Feet
MISSISSIPPIAN SYSTEM	
Kinderhook and Osage Series	
Cuyahoga formation	
RACCOON MEMBER	
7. Siltstone and mudstone interbedded. Siltstone, light bluish gray (5 B 7/1) to medium bluish gray (5 B 5/1), iron-stained, thin-bedded to massive, hard; occurs as ledges ranging in thickness from 2 to 4 feet; contact with underlying mudstone sharp. Mudstone, medium dark gray (N4), argillaceous to silty, blocky, soft; contains clay ironstone concretions; occurs in beds which range in thickness from 3 inches to 3 feet; contact with underlying siltstone gradational. Base of unit covered.	64
6. Covered interval	3.0
Kinderhook Series	
Sunbury shale	
5. Shale, black (N1), fissile; basal contact sharp.	28
Berea sandstone	
4. Sandstone, grayish orange (10 YR 7/4) to dark greenish gray (5 GY 4/1), iron-stained on weathered surfaces, fine-grained, well-sorted, massive, very hard, ledge-forming; quartz overgrowths; marcasite concretions; basal contact sharp	5.5
Bedford shale	
3. Mudstone, grayish red (10 R 4/2) changing to brownish gray (5 YR 4/1) about 35 feet above the base of the unit, very slightly silty, slightly micaceous, soft, blocky but becoming fissile in upper portion; occasional thin ledges of marcasitic or pyritic siltstone less than an inch in thickness in upper few feet; base covered.	66
2. Covered interval	23
DEVONIAN SYSTEM	
Ohio shale	
1. Shale, black (N1), very slightly silty, fissile, brittle, intermittently exposed downstream; thickness not measured.	

Elevation at top of exposed Ohio shale 775 feet (Paulin altimeter)

O. G. S. 14573

Stratigraphic section of Mississippian strata in section 12, Madison Township, Franklin County, section 13, Madison Township, Pickaway County, and section 18, Bloom Township, Fairfield County, East Columbus quadrangle.

Measured along Big Run from the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of section 12, Madison Township, Franklin County, to its intersection in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ of section 18, Bloom Township, Fairfield County, with the tributary which heads in the NW$\frac{1}{4}$ of section 17, Bloom Township; thence up the tributary to a point approximately a quarter of a mile west of the north-south road running between sections 17 and 18, Bloom Township.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
RACCOON MEMBER

9. Covered, but with Raccoon float. 20

8. Siltstone and mudstone interbedded. Siltstone, light bluish gray (5 B 7/1) to medium bluish gray (5 B 5/1), iron-stained, thin-bedded to massive, hard, ledge-forming; siltstone layers range in thickness from 2 to 4 feet; they grade upward into mudstone but overlie the mudstone beds beneath with sharp contact.
Mudstone, medium dark gray (N4), argillaceous to slightly silty, blocky, soft; thickness ranges from 3 inches to 3 feet.
Unit has sharp basal contact overlain by a massive siltstone ledge 70

7. Mudstone, medium light gray (N6), iron-stained, soft; grades downward into unit 6 in a transition zone 1 to 2 inches in thickness . . 5.0

Kinderhook Series
Sunbury shale

6. Shale, black (N1), iron-stained on weathered surfaces, fissile; base covered . . 17

5. Covered interval. 7

Berea sandstone

4. Sandstone, grayish orange (10 YR 7/4) to dark greenish gray (5 GY 4/1), iron-stained on weathered surfaces, well-sorted, fine-grained, hard, massive, ledge-forming; quartz overgrowths; occasional marcasite concretions; oscillation ripple marks with crests trending S. 70° E.; basal contact sharp. 3.0

Underlying the 3-foot ledge of Berea sandstone, and separated from it by 5 inches of mudstone similar in appearance to the upper portion of unit 3, is a channel deposit lithologically similar to the overlying sandstone. Shown in cross section at the small waterfall whose lip is formed by the Berea, the channel deposit has a maximum thickness of 5 feet, a maximum width of approximately 50 feet, and truncates the horizontal beds of unit 3.

Bedford shale

3. Mudstone, grayish red (10 R 4/2) becoming medium gray (N5) in upper 30 feet, very slightly silty, slightly micaceous, blocky, soft; small pyrite concretions with well developed crystals in upper few feet; base covered. . . . 62

Feet

2. Covered interval. 23

DEVONIAN SYSTEM
Ohio shale

1. Shale, black (N1), very slightly silty, fissile, brittle, intermittently exposed downstream; thickness not measured.

Elevation at top of exposed Ohio shale 775 feet (Paulin altimeter)

O. G. S. 14574

Stratigraphic section of Mississippian strata in section 30, Richland Township, Fairfield County, Thornville quadrangle.

Measured in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ of the section, in the stream just north of its intersection with the road.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

4. Siltstone, yellowish gray (5 Y 7/2), very thin bedded, slightly micaceous; basal contact sharp. 7.0

ALLENSVILLE MEMBER

3. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), iron-stained, poorly sorted, fine- to coarse-grained; grains subangular; abundant quartz overgrowths; massive, hard; basal contact sharp 2.0

2. Interbedded siltstone and mudstone, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4); consists of thin, hard beds of siltstone about 1 inch thick alternating with intergradational, slightly silty mudstones ranging in thickness from 1 to 4 inches; basal contact sharp. 2.7

1. Sandstone, moderate yellowish brown (10 YR 5/4), poorly sorted, fine- to coarse-grained; grains subrounded; very friable, massive, ferruginous, hydrous iron oxide bands; basal contact covered. 2.8

Elevation at base of section 909 feet (Paulin altimeter)

O. G. S. 14575

Stratigraphic section of Mississippian strata in section 9, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ NE$\frac{1}{4}$ of the section west of the railroad track on the west valley wall of Rush Creek half a mile southeast of B. M. 821.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

5. Siltstone, yellowish gray (5 Y 7/2), iron-stained, thin-bedded, slightly micaceous, base not seen. 5.0

4. Covered interval. 15.5

3. Mudstone, moderate olive brown (5 Y 4/4), silty, soft, blocky, badly weathered; basal contact sharp. 1.0

ALLENSVILLE MEMBER

2. Sandstone, light olive brown (5 Y 5/6) to dark yellowish orange (10 YR 6/6), fine- to medium-grained with additional sand of coarse size in some zones, hard, massive, ledge-forming; basal contact gradational 6.0

1. Sandstone, moderate olive brown (5 Y 4/4), very fine grained, thin-bedded, finely laminated, micaceous; occasional 1/2-inch layers of very coarse grained ferruginous sand with abundant quartz overgrowths; base covered 0.5

Elevation at base of section 807 feet (Paulin altimeter)

O. G. S. 14576

Stratigraphic section of Mississippian strata in section 17, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured in the southern half of the NE$\frac{1}{4}$ of the section along the road which climbs the east valley wall of the south-flowing tributary of Raccoon Run.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

4. Siltstone, moderate olive brown (5 Y 4/4), thin-bedded, finely laminated, slightly micaceous; occasional horizons with abundant brachiopods; generalized description based on intermittent, slumped exposures; float blocks extending 10 to 15 feet above the top of unit 4 are soft and reddish in color; base of unit covered by slump. 90

ALLENSVILLE MEMBER

3. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6); consists of subangular, fine- to medium-grained sand; coarse-grained sand with quartz overgrowths in some zones; massive, weathering thin- to medium-bedded; somewhat ledge-forming; basal contact gradational 4.0

2. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted; consists of subangular fine- and medium-grained sand with occasional local concentrations of coarse-grained sand; thin- to medium-bedded, soft; basal contact sharp. 4.3

1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), poorly sorted; consists of subangular to subrounded fine- to coarse-grained sand with coarse-grained sand predominant; quartz overgrowths common; ferruginous, very friable; base covered 0.5

Elevation at base of section 834 feet (Paulin altimeter)

O. G. S. 14577

Stratigraphic section of Mississippian strata in section 17, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured in the NW$\frac{1}{4}$ of the section along the east-west road and in a small ravine just south of the road in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ of the section.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

7. Covered; Vinton float along road ditch to hilltop; consists of thin- to medium-bedded siltstone.

ALLENSVILLE MEMBER

6. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted, fine- to coarse-grained; coarse-grained sand predominant; quartz overgrowths abundant; hydrous iron oxide bands; friable; basal contact sharp. 0.2

5. Sandstone, moderate olive brown (5 Y 4/4), fine-grained, thin- to medium-bedded, slightly micaceous; scattered grains of coarse sand; basal contact sharp 2.0

4. Siltstone, dark yellowish brown (10 YR 4/2), thin-bedded, slightly micaceous, soft; base covered. 2.0

3. Covered interval 3.0

2. Sandstone, moderate yellowish brown (10 YR 5/4), iron-stained, very fine grained; occasional layers 1/4 inch to 4 inches thick of poorly sorted, fine- to coarse-grained sandstone in which the predominant grain size is coarse; coarse grains are subangular to subrounded, coated with hydrous iron oxide and commonly show quartz overgrowths; unit is medium bedded, micaceous; basal contact gradational 6.0

BYER MEMBER

1. Siltstone, light olive brown (5 Y 5/6) to pale olive (10 Y 6/2), slightly iron stained, thin- to medium-bedded, hard, slightly micaceous; base covered 8.0

Elevation at base of section 840 feet (Paulin altimeter)

O. G. S. 14578

Stratigraphic section of Mississippian strata in sections 7 and 18, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured along the northwest-southeast road from its intersection with the eastern boundary of section 18 in the NE¼ NE¼ of the section to the first house west of the 963-foot road corner in the SW¼ SE¼ of section 7.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
16. Siltstone, grayish orange (10 YR 7/4) to moderate olive brown (5 Y 4/4); mottled black iron stain on bedding surfaces; thin-bedded, micaceous, soft, intermittently exposed; base covered.	55
15. Covered interval; abundant Vinton float but no Allensville float	40
ALLENSVILLE MEMBER	
14. Sandstone, dark yellowish orange (10 YR 6/6); mottled iron staining on weathered surfaces; consists of subangular fine-grained sand with abundant scattered grains and local concentrations of subrounded medium- to coarse-grained sand; quartz overgrowths common; medium-bedded, ferruginous, soft, friable; basal contact gradational	3.0
13. Siltstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4); mottled black on weathered surfaces; thin-bedded, micaceous, soft; scattered subrounded grains of medium-grained sand commonly showing overgrowths; basal contact sharp.	2.5
12. Sandstone, grayish orange (10 YR 7/4); mottled iron staining; very poorly sorted; grain size ranges from clay to medium-grained sand; thin- to medium-bedded; occasional small clay nodules; quartz overgrowths common; scattered crinoid columnals; basal contact gradational . .	1.2
11. Sandstone, moderate yellowish brown (10 YR 5/4) to dark yellowish orange (10 YR 6/6); mottled iron stain on weathered surfaces; fine-grained, massive; irregular local concentrations of subangular to subrounded medium- to coarse-grained sand which commonly shows quartz overgrowths; basal contact sharp	1.6
10. Sandstone, moderate yellowish brown (10 YR 5/4), coarse-grained; grains subangular to subrounded, coated with hydrous iron oxide; abundant interstitial fine-grained sand; friable; basal contact sharp	0.1
9. Siltstone, moderate yellowish brown (10 YR 5/4); mottled black on weathered surfaces; argillaceous, sandy, micaceous, massive; weathers blocky; base not seen.	1.3
8. Covered interval	1.8
7. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), poorly sorted; consists of subrounded medium- to coarse-grained sand commonly with overgrowths in a matrix of fine-grained ferruginous sand; differential hydrous iron oxide concentration results in color banding with bands varying from 1/4 inch to 1/2 inch in thickness; coarse-grained sand more abundant in the darker bands; medium-bedded, hard; basal contact sharp. . .	2.3
6. Siltstone, moderate olive brown (5 Y 4/4); weathers to mottled grayish red (10 R 4/2) and blackish red (5 R 2/2); argillaceous, sandy, with abundant fine-grained sand and rare subangular grains of coarse-grained sand; soft, blocky to thin-bedded; hydrous iron oxide concentrated on bedding surfaces; basal contact sharp.	3.0
5. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), iron-stained, poorly sorted; consists of abundant grains of randomly concentrated, subrounded, coarse-grained sand in a matrix of fine-grained, subangular, ferruginous sand; scattered small clay nodules up to 1/2 inch in diameter, quartz overgrowths common; massive, hard; base covered	1.0
4. Covered interval.	3.0
3. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), poorly sorted; consists of subangular coarse-grained sand in a matrix of fine-grained sand and hydrous iron oxide; quartz overgrowths common on the coarse grains; variable concentration of coarse-grained sand results in a vague banding with alternate bands of abundant coarse-grained sand and relatively less abundant coarse-grained sand ranging in thickness from 1/4 to 1/2 inch and lying parallel to the bedding; thin hydrous iron oxide bands along bedding surfaces; hard; base covered	1.0
2. Covered interval.	2.0
BYER MEMBER	
1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), fine-grained; grains subangular; quartz overgrowths; occasional grains of subrounded, coarse-grained sand, medium-bedded, hard; base covered.	0.5

Elevation at base of section 852 feet (hand level)

O. G. S. 14579

Stratigraphic section of Mississippian strata in section 18, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured in the NW¼ NW¼ of the section along the road which climbs the hill immediately east of the township line.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
4. Siltstone, light olive gray (5 Y 5/2); weathers to grayish red (10 R 4/2); mottled black on bedding surfaces; thin-bedded, soft; base covered.	3.0
3. Covered interval.	7.0
ALLENSVILLE MEMBER	
2. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4) to grayish orange (10 YR 7/4); mottled black iron stain on bedding surfaces; poorly sorted; consists of subrounded, medium- to coarse-grained sand in a matrix of fine-grained sand; varies from coarse-grained sandstone to fine-grained sandstone with rare grains of coarse sand; quartz overgrowths common; irregular hydrous iron oxide bands; thin-bedded except for a 1-foot ledge occurring 5 feet above the base of the unit; poorly exposed; basal contact sharp	8.1
BYER MEMBER	
1. Siltstone, moderate yellowish brown (10 YR 5/4); mottled black on bedding surfaces; thin- to medium-bedded, soft; occasional grains of subrounded medium- to coarse-grained sand in upper portion; base covered.	35.0

Elevation at base of section 868 feet (Paulin altimeter)

O. G. S. 14580

Stratigraphic section of Mississippian strata in section 28, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ NE$\frac{1}{4}$ of the section on the east valley wall of the north-flowing tributary of Rush Creek, near the right-angle bend in the farm lane.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
6. Covered; abundant Vinton float.	
ALLENSVILLE MEMBER	
5. Sandstone, grayish orange (10 YR 7/4) to light brown (5 YR 5/6), poorly sorted, fine-grained to very coarse grained; grains subangular; overgrowths common; heavy hydrous iron oxide bands in zones where coarser grains predominate; thin- to medium-bedded; scattered crinoid columnals; base not seen	11.2
4. Covered interval.	1.2
3. Sandstone, moderate olive brown (5 Y 4/4), fine-grained with rare grains of rounded coarse-grained sand; overgrowths abundant; micaceous; basal contact sharp.	0.7
2. Sandstone, light brown (5 Y 4/4); consists of subangular to subrounded, medium- to coarse-grained sand in a matrix of fine-grained ferruginous sand; overgrowths common; friable; basal contact sharp	0.3
BYER MEMBER	
1. Siltstone, moderate olive brown (5 Y 4/4); light mottled iron staining on bedding surfaces; shaly to thin-bedded, finely laminated, moderately hard; base not seen	10.5

Elevation at base of section 796 feet (Paulin altimeter)

O. G. S. 14581

Stratigraphic section of Mississippian strata in section 28, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ of the section in a road cut immediately east of the right-angle bend in the highway.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
5. Siltstone, yellowish gray (5 Y 7/2) to medium bluish gray (5 B 5/1); iron-stained on bedding surfaces; thin-bedded, slightly micaceous, hard; rare brachiopods; basal contact gradational.	16.0
4. Mudstone, medium bluish gray (5 B 5/1); iron-stained on bedding surfaces; blocky, soft, very slightly silty, slightly micaceous; base covered.	1.2
3. Covered interval	4.7
2. Mudstone, light olive gray (5 Y 5/2), slightly iron stained, very slightly silty, soft, blocky, slightly micaceous; basal contact sharp.	1.3
ALLENSVILLE MEMBER	
1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate olive brown (5 Y 4/4), iron-stained; varies from fine-grained sandstone with occasional medium and coarse grains to medium- to coarse-grained sandstone with interstitial fine-grained ferruginous sand; grains generally subangular; hydrous iron oxide bands up to 1/4 inch thick; irregularly shaped clay nodules; base covered.	5.0

Elevation at base of section 790 feet (Paulin altimeter)

O. G. S. 14582

Stratigraphic section of Mississippian strata in section 16, Berne Township, Fairfield County, Lancaster quadrangle.

Measured along Crawfis Road from a point above the house in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ of the section to the hilltop intersected by the eastern boundary of the section.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
ALLENSVILLE MEMBER	
5. Allensville float blocks on hilltop in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ of section 15; elevation 1000 feet (estimated from topographic contours).	
BYER MEMBER	
4. Siltstone, dark yellowish orange (10 YR 6/6) to light brown (5 YR 5/6); mottled iron stains; thin- to medium-bedded, soft; base covered. . .	28
3. Covered interval.	13
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
2. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), medium- to coarse-grained; grains subangular; quartz overgrowths abundant; massive, friable, ledge-forming; base not seen	39
CUYAHOGA FORMATION, UNDIFFERENTIATED	
1. Sandstone, light brown (5 YR 5/6), fine-grained; occasional grains of subrounded, medium-grained sand; soft, friable, thin-bedded, poorly exposed; base covered	5

Elevation at base of section 895 feet (Paulin altimeter)

O. G. S. 14583

Stratigraphic section of Mississippian and Pennsylvanian strata in section 25, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured along the stream from the house in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ to the intersection of the stream with the Bethel Church road approximately half a mile south of the 951-foot road corner.

	Feet
PENNSYLVANIAN SYSTEM	
Pottsville Group	
11. Mudstone, moderate olive brown (5 Y 4/4), iron-stained, slightly silty, soft, very thin bedded; some tendency to weather fissile; carbonaceous fragments common; occasional thin, hard, intercalated siltstones; grades into thin-bedded, fine-grained sandstone in upper 4 feet; base covered.	14.0
10. Covered interval.	2.3
9. Sandstone, pale yellowish brown (10 YR 6/2) to dark yellowish orange (10 YR 6/6), poorly sorted, fine- to coarse-grained, massive, friable, overgrowths abundant; lower 3 inches highly ferruginous and with abundant carbonaceous fragments; badly weathered and slumped; basal contact sharp. . .	2.8
8. Coal, dull, sooty.	2.3
7. Covered interval.	1.0
6. Sandstone, yellowish gray (5 Y 7/2) to dark yellowish orange (10 YR 6/6), poorly sorted, fine- to coarse-grained, massive, friable; quartz overgrowths abundant; carbonaceous fragments abundant near base; basal contact sharp.	7.0
5. Mudstone, medium light gray (N6), slightly silty, blocky, soft, carbonaceous in lower portion; occasional intercalations of very thin ferruginous siltstone; grades upward into light gray, iron-stained clay with a 1/2-inch carbonaceous layer at the top; basal contact of unit sharp.	4.9
4. Siltstone, grayish red (5 R 4/2), thin- to medium-bedded, hard, blocky; abundant carbonaceous fragments on upper surface; basal contact sharp	1.8
3. Sandstone, yellowish gray (5 Y 7/2) to pale red purple (5 RP 6/2) to dark yellowish orange (10 YR 6/6), poorly sorted, fine- to medium-grained, medium-bedded, hard, ferruginous; carbonaceous plant fragments up to 1 inch in length abundant near base; basal contact sharp	4.9
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
2. Clay, medium light gray (N6), slightly silty, plastic; occasional thin beds of siltstone similar in lithologic character to unit 1; siltstone beds become increasingly abundant downward; basal contact gradational	3.0
1. Siltstone, light olive gray (5 Y 5/2) to moderate yellowish brown (10 YR 5/4), iron-stained, thin-bedded, finely laminated, slightly micaceous, hard; base not seen	1.0

Elevation at base of section 872 feet (Paulin altimeter)

O. G. S. 14584

Stratigraphic section of Mississippian strata in section 27, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ and the NE$\frac{1}{4}$ SE$\frac{1}{4}$ of the section on the hillside north of the road immediately across the road from the first house east of the 794-foot road corner.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation, unsubdivided

7. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), poorly sorted, fine- to coarse-grained; grains subangular; thin-bedded; iron staining gives laminated effect; friable, slope-forming; weathers much more rapidly than underlying unit; basal contact sharp. 1.0

6. Sandstone, dark yellowish orange (10 YR 6/6) to moderate brown (5 YR 4/4), poorly sorted, fine- to medium-grained; grains subangular, commonly with overgrowths; massive, crossbedded, friable, ledge-forming; heavy hydrous iron oxide bands and nodules stand out as ribs and nodes on the weathered surface; base covered. 4.0

5. Covered interval. 2.1

4. Sandstone, same as unit 6. . . . . 5.0

3. Covered interval. 22.0

2. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), medium- to coarse-grained; consists of subrounded sand grains coated with hydrous iron oxide and a small amount of very fine grained interstitial sand; crossbedding accentuated by differential iron staining; extremely friable; basal contact sharp. 2.2

1. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), heavily iron stained, fine-grained, thin- to medium-bedded, micaceous, hard, brittle; base not seen. 20.0

Elevation at base of section 800 feet (Paulin altimeter)

O. G. S. 14585

Stratigraphic section of Mississippian strata in section 22, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of the section, along the road which ends approximately a quarter of a mile south of the 1059-foot road corner; thence north a tenth of a mile along the north-south road to the hilltop.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

5. Covered; Vinton float; thickness estimated from topographic contours. 30

4. Sandstone, dusky yellow (5 Y 6/4); mottled iron stain on bedding surfaces and weathered surfaces; very fine grained, thin- to medium-bedded; beds have a slight tendency to form ledges; scattered ferruginous casts of brachiopods and crinoid columnals; fossils particularly abundant in a restricted zone 3-1/2 feet above the base of the unit; basal contact sharp. 4.0

3. Mudstone, moderate olive brown (5 Y 4/4) to moderate yellowish brown (10 YR 5/4); mottled iron stain on weathered surface, soft, blocky to thin-bedded, slightly silty at base with siltiness gradually increasing upward so that upper portion consists of relatively hard, thin-bedded siltstone; slightly micaceous; base covered. 28.4

2. Covered interval 5.0

ALLENSVILLE MEMBER

1. Sandstone, dark yellowish orange (10 YR 6/6); poorly sorted; consists of medium- to coarse-grained sand in a matrix of fine-grained ferruginous sand; ratio of coarse-grained to fine-grained sand varies rapidly and with no apparent pattern; grains subangular, commonly with overgrowths; medium-bedded; friable except in zones of unusually heavy hydrous iron oxide accumulation; hydrous iron oxide bands common; base not seen. 10.0

Elevation at base of section 963 feet (Paulin altimeter)

O. G. S. 14586

Stratigraphic section of Mississippian and Pennsylvanian strata in section 35, Rush Creek Township, Fairfield County, Logan quadrangle.

Measured in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ and SE$\frac{1}{4}$ SE$\frac{1}{4}$ of the section along the tributary of Rush Creek which flows roughly parallel to the Hocking County line about two-tenths of a mile north of the county line.

Feet

PENNSYLVANIAN SYSTEM
Pottsville Group

7. Sandstone, white (N9); slightly mottled iron staining; fine-grained, medium-bedded, very hard, somewhat micaceous; base covered. . 1.5

6. Covered interval; abundant float of fine-grained, thin-bedded, micaceous sandstone in upper 5 feet. 54

5. Alternating fine- to medium-grained, massive sandstone and thin-bedded fine-grained sandstone as in units 2 and 3 respectively; very poorly exposed 6.0

4. Sandstone, same as unit 2 . . . . 2.0

3. Sandstone, dusky yellow (5 Y 6/4), fine-grained, very thin bedded, finely laminated, soft, slope-forming; abundant large mica flakes and carbonaceous specks as much as 1 mm in diameter on bedding surfaces; sharp contacts above and below. 3.0

2. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted, fine- to medium-grained; grains subangular, with scattered overgrowths;

	Feet
massive, friable; tends to form ledges 1 to 3 feet in thickness; micaceous; small carbonaceous fragments; exposure intermittent; basal contact sharp.	5.0

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

1. Siltstone, yellowish gray (5 Y 7/2) to light olive gray (5 Y 5/2); mottled iron staining; thin- to medium-bedded, hard, slightly micaceous; exposure poor and intermittent; base not seen	73

Elevation at base of section 876 feet (Paulin altimeter)

O. G. S. 14587

Stratigraphic section of Mississippian strata in section 36, Greenfield Township, Fairfield County, Lancaster quadrangle.

Measured in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ of the section on the northeast side of the small hill located directly across the highway from the cemetery.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
CUYAHOGA FORMATION, UNDIFFERENTIATED

2. Sandstone, yellowish orange (10 YR 7/6), fine- to medium-grained; grains subangular; medium-bedded, but becoming thin bedded near top, slightly friable, micaceous; some weathered feldspar; abundant clay galls up to 1 inch in diameter; heavy hydrous iron oxide accumulations along some joints and bedding surfaces; basal contact sharp.	13.0

BLACK HAND MEMBER

1. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted, fine- to medium-grained with scattered grains of coarse-grained sand; massive, friable, micaceous; fragments of weathered feldspar common; clay galls up to 1 inch in diameter scattered throughout unit, but concentrated with particular abundance in occasional layers about 1 inch thick; irregular hydrous iron oxide bands as thick as 3/4 inch; hydrous iron oxide bands occasionally form concretions 1 foot in diameter consisting of white, unconsolidated sand surrounded by a heavy hydrous iron oxide band; base not seen	8.0

Elevation at base of section 887 feet (Paulin altimeter)

O. G. S. 14588

Stratigraphic section of Mississippian strata in section 12, Hocking Township, Fairfield County, Lancaster quadrangle.

Measured in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ of the section in an excavation on the northeast side of the hill.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

5. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted, fine- to medium-grained with occasional grains of coarse-grained sand; grains subangular; thin- to medium-bedded, soft, somewhat friable, micaceous; basal contact sharp.	16.0
4. Sandstone, grayish orange (10 YR 7/4) to light brown (5 YR 5/6), poorly sorted, varies from fine grained to medium grained with occasional grains of coarse sand; grains subangular; massive, very soft and friable, slightly micaceous; irregular hydrous iron oxide bands; basal contact sharp	23.4
3. Clay, light brownish gray (5 YR 6/1), sandy; contains abundant fragments of sandstone; plastic, locally iron stained, lenticular; thins to 2 inches in a distance of 8 feet before passing under cover; contacts sharp.	1.8
2. Sandstone, moderate reddish brown (10 R 4/6) to dark yellowish orange (10 YR 6/6), fine-grained with occasional grains of medium- to coarse-grained sand; grains subangular; medium-bedded; some mica and weathered feldspar; abundant very thin hydrous iron oxide bands; occasional lenses of gray, plastic, sandy clay up to 2 inches thick in the upper 2-1/2 feet; soft, especially in the red portions; basal contact sharp. .	10.5
1. Sandstone, grayish orange (10 YR 7/4), locally pale reddish brown (10 R 5/4), poorly sorted, fine- to coarse-grained; grains subangular; massive, friable, soft, slightly micaceous; occasional hydrous iron oxide bands up to 1/2 inch in thickness; scattered clay galls up to 1/2 inch in diameter; base not seen. . . .	4.0

Elevation at base of section 893 feet (Paulin altimeter)

O. G. S. 14589

Stratigraphic section of Mississippian strata in section 15, Pleasant Township, Fairfield County, Thurston quadrangle.

Measured in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ of the section along the road about four-tenths of a mile east of Pleasant Run.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
ALLENSVILLE MEMBER

5. Sandstone, grayish orange (10 YR 7/4), very fine grained, but with rare grains of subrounded, coarse-grained sand, thin- to medium-bedded, hard, micaceous; basal contact sharp. .	3.0

	Feet
4 Sandstone, moderate yellowish brown (10 YR 5/4); consists of subrounded, medium- to coarse-grained sand in a matrix of fine-grained sand; quantity of medium- to coarse-grained sand varies rapidly so that beds as much as 2 inches in thickness of medium- to coarse-grained sandstone alternate with fine-grained sandstone containing occasional coarser grains; the coarser portions tend to be more friable and more ferruginous; basal contact sharp.	0.8
3. Shale, pale yellowish brown (10 YR 6/2), slightly silty, micaceous, soft; basal contact sharp	0.1
2. Sandstone, moderate brown (5 YR 3/4); subrounded medium-grained to very coarse grained sand with interstitial clay and hydrous iron oxide; very friable; basal contact sharp. .	0.2
BYER MEMBER	
1. Sandstone, dark yellowish orange (10 YR 6/6), very fine grained; occasional subrounded grains of coarse-grained sand; thin- to medium-bedded, soft, slightly micaceous; scattered crinoid columnals; base not seen	4.0

Elevation at base of section 955 feet (Paulin altimeter)

O. G. S. 14590

Stratigraphic section of Mississippian strata in section 7, Berne Township, Fairfield County, Lancaster quadrangle.

Measured on the west and south sides of the hill in the NW$\frac{1}{4}$ of the section.

	Feet
MISSISSIPPIAN SYSTEM	
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
3. Covered; abundant float of sandstone and conglomerate. Sandstone, grayish orange (10 YR 7/4), poorly sorted, medium- to coarse-grained; quartz overgrowths abundant; friable; occasional clay pebbles. Conglomerate consists of abundant rounded quartz pebbles in a matrix of hard, ferruginous, poorly sorted, medium- to coarse-grained sandstone; pebbles as large as 3 inches in diameter, but most commonly diameter ranges from 1/4 to 1 inch.	4.0
RACCOON MEMBER	
2. Siltstone, medium light gray (N6), iron stained on weathered surfaces, thin-bedded, hard, slightly micaceous; description based on float and intermittent exposures.	15.0
BLACK HAND MEMBER	
1. Sandstone, dark yellowish orange (10 YR 6/6), locally pale reddish brown (10 R 5/4); varies from fine-grained sandstone to coarse-grained sandstone with abundant quartz pebbles as large as 1/4 inch in diameter; bedding varies from thin-bedded to massive with no apparent relationship between bedding and grain size; thin- to medium-bedded portions commonly grade laterally into massive sandstone, and in one instance thin- to medium-bedded sandstone appears to be truncated laterally by massive sandstone; clay galls as large as 3 inches in diameter scattered throughout unit; galls are micaceous and silty, and occur in particular abundance in lenses up to 2 feet in thickness which can be traced for several tens of feet before they wedge out; lenses consist of a mixture of clay galls and sandstone fragments; irregular hydrous iron oxide bands common; sandstone is friable, somewhat micaceous, and quartz overgrowths are abundant; base not seen.	88

Elevation at base of section 813 feet (Paulin altimeter)

O. G. S. 14591

Stratigraphic section of Mississippian strata in section 19, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the SW$\frac{1}{4}$ of the section along Tarkiln Road from a point located approximately three-tenths of a mile southeast of the 1094-foot road corner to the 1094-foot road corner; thence southwest about 300 feet along the road toward the Boys' Industrial School.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
BYER MEMBER	
25. Siltstone, dusky yellow (5 Y 6/4), thin- to medium-bedded, slightly micaceous, soft; base not seen.	0.5
24. Covered interval.	1.0
BERNE MEMBER	
23. Sandstone, moderate yellowish brown (10 YR 5/4), poorly sorted, fine-grained to very coarse grained; grains generally subangular, but largest grains approach subrounded; grains coated with hydrous iron oxide; no apparent bedding; poorly consolidated; basal contact sharp	0.7
22. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), poorly sorted, fine- to medium-grained with occasional coarse grains; relatively hard; basal contact sharp	0.3
21. Conglomerate, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4); consists of subrounded quartz pebbles as large as 1/4 inch in diameter in a matrix of subangular, medium-grained, ferruginous sand; no apparent bedding; poorly consolidated; base covered.	0.7

	Feet
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
20. Covered; a very small exposure of sandstone as in unit 19 occurs 10 feet above base.	12.2
19. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), fine- to medium-grained; grains subangular; massive in upper 5 feet, but thin- to medium-bedded in lower portion; friable; basal contact sharp.	7.7
18. Conglomerate, pale yellowish brown (10 YR 6/2); consists of subrounded to rounded quartz pebbles generally near 1/4 inch in diameter but with a maximum diameter of 1-1/2 inches in a matrix of fine- to medium-grained sandstone with subangular grains; massive; basal contact sharp	1.5
17. Sandstone, grayish orange (10 YR 7/4), iron-stained, poorly sorted, fine- to medium-grained with thin layers containing very coarse grained sand and pebbles up to 1/8 inch in diameter, massive, but near top passes laterally into thin- to medium-bedded sandstone with cross beds dipping both northwest and southeast; massive again in uppermost 1 foot; base not seen	7.9
16. Covered interval	0.5
15. Sandstone, grayish orange (10 YR 7/4), very fine grained, very thin bedded, micaceous; abundant weathered feldspar; basal contact sharp	3.2
14. Sandstone, grayish orange (10 YR 7/4) to light brown (5 YR 5/6); varies from fine- to coarse-grained, but medium-grained sand predominant; occasional pebbly zones with pebbles as large as 1/2 inch but usually near 1/8 inch in diameter; massive, friable; basal contact sharp	4.8
13. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), fine- to medium-grained; grains subangular; thin-bedded, somewhat friable; basal contact sharp.	4.8
12. Sandstone, grayish orange (10 YR 7/4), poorly sorted, fine-grained to very coarse grained, but consists predominantly of medium- to coarse-grained sand with some overgrowths; occasional pebbly zones with pebbles generally near 1/8 inch in diameter, but with a maximum diameter of 1/2 inch; massive, friable; base covered	16.5
11. Covered interval.	2.0
10. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), iron-stained, fine- to coarse-grained; grains subangular; thin-bedded, friable; basal contact sharp.	2.5
9. Sandstone, dark yellowish orange (10 YR 6/6) to grayish orange (10 YR 7/4), irregularly iron stained, poorly sorted, fine- to coarse-grained; grains subangular, commonly with overgrowths; massive, friable; base covered .	11.0
8. Covered interval.	20.4
7. Sandstone, dark yellowish orange (10 YR 6/6) to light brown (5 YR 5/6), fine- to medium-grained; grains subangular; massive, friable, soft; base covered	4.0
6. Covered interval.	3.3
5. Sandstone, light brown (5 YR 5/6), poorly sorted, fine- to coarse-grained; grains subangular, commonly with overgrowths; thin- to medium-bedded, friable, slightly micaceous; occasional thin hydrous iron oxide bands; base not seen.	5.0
4. Covered interval.	0.9
3. Sandstone, light brown (5 YR 5/6), medium-grained with occasional grains of coarse size; grains subangular, commonly with overgrowths; massive, slightly friable; base covered. . . .	1.6
2. Covered interval.	3.0
1. Sandstone, light brown (5 YR 5/6), fine- to medium-grained; grains subangular; friable; hydrous iron oxide band 1/4 inch in thickness at top of unit; base covered	0.7

Elevation at base of section 980 feet (hand level)

O. G. S. 14592

Stratigraphic section of Mississippian strata in section 8, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ on the north valley wall of Brushy Fork just southeast of Freshport School and along the road east of Freshport School on the hillside above the farmhouse.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
BYER MEMBER	
5. Sandstone, dark yellowish orange (10 YR 6/6), very fine grained to fine-grained; grains subangular, with occasional overgrowths; thin- to medium-bedded, soft, slightly micaceous; very thin irregular hydrous iron oxide bands; base covered.	3.3
4. Covered interval.	2.7
BERNE MEMBER	
3. Sandstone, grayish orange (10 YR 7/4), generally fine-grained, but with very thin layers and lenses of subangular medium-grained sand and occasionally coarse-grained and very coarse grained sand; overgrowths common; hydrous iron oxide bands up to 1/2 inch in thickness; friable except where excessively ferruginous	0.2

	Feet
2. Sandstone, grayish orange (10 YR 7/4) to light brown (5 YR 6/4), very poorly sorted; consists of fine-grained to very coarse grained sand and pebbles as large as 1/4 inch in diameter with interstitial clay and hydrous iron oxide; grains generally subangular, though larger pebbles are subrounded; quartz overgrowths common; massive, hard; hydrous iron oxide bands up to 1/2 inch in thickness; base not seen.	0.9

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

1. Sandstone, grayish orange (10 YR 7/4), poorly sorted, fine-grained to very coarse grained, but predominantly medium- to coarse-grained; grains subangular; occasional pebbly layers with subrounded to rounded pebbles usually smaller than 1/4 inch in diameter, but with a maximum diameter of 1/2 inch; massive, crossbedded; cross beds dip both northwest and southeast; friable, cliff-forming; differential hydrous iron oxide concentration reflected in development of ribs, nodes, and honeycomb weathering on weathered surface; quartz overgrowths common; base not seen.	60

Elevation at base of section 965 feet (Paulin altimeter)

O. G. S. 14593

Stratigraphic section of Mississippian strata in section 27, Madison Township, Fairfield County, Lancaster quadrangle.

Measured in the NW¼ SW¼ of the section along the road which climbs the north side of the 1200-foot hill.

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BYER MEMBER

	Feet
12. Covered to hilltop; Byer float.	8.0
11. Siltstone, light olive brown (5 Y 5/6) to dark yellowish orange (10 YR 6/6), thin- to medium-bedded, slightly micaceous; base covered.	0.2
10. Covered interval	3.0

BERNE MEMBER

9. Sandstone, moderate brown (5 YR 4/4), very poorly sorted; consists of subangular sand varying from fine-grained to very coarse grained with abundant subrounded to rounded pebbles up to 1/2 inch in diameter in the lower portion; grades upward into fine-grained sandstone with scattered grains of coarse-grained sand and granules; thin- to medium-bedded, friable, ferruginous	1.6
8. Covered interval	3.6
7. Sandstone, moderate yellowish brown (10 YR 5/4), fine-grained with occasional grains of medium- and coarse-grained sand and scattered pebbles up to 1/4 inch in diameter, massive, hard, slightly micaceous; basal contact gradational.	1.4
6. Sandstone, moderate yellowish brown (10 YR 5/4), conglomeratic; consists of subangular, very coarse grained sand and subrounded to rounded pebbles generally near 1/4 inch in diameter but as large as 1/2 inch in diameter in a matrix of poorly sorted, fine- to medium-grained, subangular, ferruginous sand; pebbles decrease in abundance upward; quartz overgrowths common; massive, hard; basal contact sharp	0.5

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

5. Sandstone, light brown (5 YR 5/6), poorly sorted, fine-grained to very coarse grained, pebbly; pebbles generally smaller than 1/4 inch in diameter; largest pebble observed 2 inches in diameter; massive; friable, ledge-forming; occasional hydrous iron oxide bands; intermittently exposed; basal contact sharp . .	36.6
4. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted, fine- to medium-grained with occasional coarse grains; grains subangular; thin- to medium-bedded, very soft and friable, slightly micaceous; passes downward into thin-bedded portion of unit 3; contact with massive portion of unit 3 not seen	2.0
3. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted, fine-grained to very coarse grained; grains subangular; massive, friable; in upper 2 feet passes laterally into thin-bedded sandstone which is fine to medium grained with pebbles up to 1/8 inch in diameter on the bedding surfaces; base covered	22.0
2. Covered interval.	4.8
1. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted; consists of subangular fine-grained to very coarse grained sand and subrounded to rounded pebbles up to 1/4 inch in diameter but usually near 1/16 inch in diameter; massive, friable; base not seen	1.7

Elevation at base of section 1120 feet (Paulin altimeter)

O. G. S. 14594

Stratigraphic section of Mississippian strata in section 34, Hocking Township, Fairfield County, Lancaster quadrangle.

Measured in the NE¼ of the section in the ravine tributary to Arney Run and at the cliff at Jacobs Ladder just east of the ravine.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BYER MEMBER

9. Covered; float consists of fine-grained, thin-bedded sandstone. 3.0

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

8. Sandstone, very pale orange (10 YR 8/2) to dark yellowish orange (10 YR 6/6), poorly sorted, fine-grained to very coarse grained, predominantly medium- to coarse-grained; grains subangular; scattered pebbles as large as 3/4 inch in diameter but generally smaller than 1/4 inch in diameter; massive, friable, cliff-forming, crossbedded; apparent dips of cross beds N. 85° E. and S. 85° W.; honeycomb weathering; some hydrous iron oxide bands; scour-and-fill structures well shown; near top of unit is an 8-inch pebbly layer overlain by 1 foot of sandstone similar to that below; base covered. 90

7. Covered interval. 72

6. Sandstone, very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4), medium- to coarse-grained; grains subangular; pebbly in upper 1-1/2 feet with pebbles generally near 1/8 inch in diameter, but occasionally as large as 1/2 inch in diameter; massive, friable; base covered. . . . 7.0

5. Covered interval. 28

RACCOON MEMBER

4. Mudstone, medium dark gray (N4), slightly silty, thin-bedded to blocky, soft, micaceous; occurs in beds ranging from 1 inch to 2 feet in thickness which are separated by thin sandstones.
Sandstone, light olive gray (5 Y 5/2), slightly iron stained, fine-grained, thin- to medium-bedded, soft and friable, slightly micaceous; occurs in layers ranging in thickness from 1 inch to 1 foot and is in sharp contact with the mudstones above and below; flow casts observed on float blocks.
Base of unit covered 6.0

3. Covered interval. 4.5

BLACK HAND MEMBER

2. Covered; abundant float and sparse, very poor exposures of sandstone as in unit 1 52

1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate reddish brown (10 R 4/6), poorly sorted; consists of subangular fine- to medium-grained sand with occasional grains of coarse-grained sand; some zones contain pebbles up to 1/4 inch in diameter and sand ranging in size from fine-grained to very coarse grained; quartz overgrowths common; massive, varying locally to thin-bedded; abundant clay galls up to 2 inches in diameter; abundant irregular hydrous iron oxide bands ranging in thickness from 1/4 to 1/2 inch; friable, very soft; occasional clay lenses whose maximum thicknesses range from 2 to 5 inches.

Feet

Clay is light gray (N7), slightly sandy, slightly micaceous, plastic; lenses are in sharp contact with the enclosing sandstone and contain very thin layers of fine-grained micaceous sand and sandstone.
Base of unit covered. 10.0

Elevation at base of section 910 feet (Paulin altimeter)

O. G. S. 14595

Stratigraphic section of Mississippian strata in section 9, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured in the SW$\frac{1}{4}$ of the section on the south valley wall of Brushy Fork behind the house located two-tenths of a mile from the western boundary of the section and along the long lane which climbs to the hilltop.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BYER MEMBER

5. Siltstone, light olive brown (5 Y 5/6) to grayish orange (10 YR 7/4), iron-stained, thin- to medium-bedded, micaceous; crinoid columnals in some zones; basal contact sharp. . . . 30

BERNE MEMBER

4. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), conglomeratic; consists of subrounded to rounded pebbles in a matrix of poorly sorted, subangular, ferruginous, fine-grained to very coarse grained sand, commonly with overgrowths; pebbles generally less than 1/4 inch in diameter, but in lower 2 inches pebbles as large as 1 inch in diameter are abundant; thin- to medium-bedded; basal contact sharp only because of tendency for unit to weather rapidly. 1.1

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

3. Sandstone, same as unit 1. 18

2. Covered interval. 32

1. Sandstone, yellowish orange (10 YR 7/6), poorly sorted, medium-grained to very coarse grained; grains subangular, commonly with overgrowths; scattered subrounded granules in the lower 60 feet and scattered pebbles and pebble washes common in remainder of unit; uppermost 3 feet unusually pebbly with pebbles as large as 1 inch in diameter; pebbles in remainder of unit range from 1/8 to 1/4 inch in diameter; massive, hard, cliff-forming, crossbedded; honeycomb weathering; hydrous iron oxide bands up to 1 inch in thickness in lower portion; cave-forming at base; base covered 190

Elevation at base of section 780 feet (Paulin altimeter)

O. G. S. 14596

Stratigraphic section of Mississippian strata in section 31, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the $NE\frac{1}{4}$ $NE\frac{1}{4}$ of the section in a steep ravine at the head of the stream which enters Blue Valley just east of Blue Valley School.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

3. Sandstone, moderate yellowish brown (10 YR 5/4), poorly sorted; sand is subangular, fine to very coarse grained, but predominantly medium grained; abundant pebbles in lower 6 feet, scattered, in thin discontinuous layers, or in conglomeratic zones as thick as 1 foot; pebbles up to 1 inch in diameter but generally smaller than 1/4 inch in diameter; massive, hard, ferruginous, crossbedded; apparent dips of cross beds 13° E. and 90° W.; cross beds developed on such a large scale that uniformly dipping beds of a single set can be traced for as much as 20 feet (the width of the outcrop where the cross beds are exposed); at base of unit a conglomeratic zone ranging in thickness from 4 inches to 1-1/2 feet rests disconformably on unit 2; the relief of the erosion surface is about 1 foot, and the conglomeratic portion grades upward into sandstone; the lower several feet of the unit pass eastward into a massive, structureless (except for some vague cross beds), conglomeratic sandstone, which ranges in thickness from 3 to 6 feet, contains pebbles as large as 1-1/2 inches in diameter, and can be traced for some distance along the cliff face to the east. 16

2. Sandstone, very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4), poorly sorted, fine- to coarse-grained, but medium-grained sand predominant; grains subangular; massive, friable; honeycomb weathering; exceptionally ferruginous layers stand out on face of outcrop suggesting bedding; apparent dips range from 12°, S. 85° E. to 18°, S. 62° E.; unit is structureless and identical in appearance to unit 1 where the face of the outcrop has been smoothed by running water; basal contact sharp. 46

1. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), poorly sorted, very fine to very coarse grained, predominantly near medium-grained; grains subangular; scattered pebbles generally smaller than 1/8 inch in diameter; massive, friable; forms a steep, smooth ledge at the head of the ravine, but completely covered on the banks of the ravine; structureless except for a few vague cross beds in the upper portion; base covered. 38

Elevation at base of section 980 feet (Paulin altimeter)

O. G. S. 14597

Stratigraphic section of Mississippian strata in section 12, Madison Township, Fairfield County, Lancaster quadrangle.

Measured in the western part of the section in the ravine which heads just south of the road in the $SE\frac{1}{4}$ $NW\frac{1}{4}$ of the section.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

7. Sandstone, pale yellowish brown (10 YR 6/2) to light brown (5 YR 5/6), fine- to medium-grained, passing upward into medium- to coarse-grained sandstone with thin pebbly streaks; pebbles usually smaller than 1/4 inch in diameter; maximum diameter 1-1/2 inches; massive, crossbedded, slightly friable, ledge-forming; poorly developed honeycomb weathering; differential hydrous iron oxide concentration reflected in the development of ribs and nodes on the weathered surface; base covered. 48

6. Covered interval. 75

5. Sandstone, coarse, massive; same as unit 1; basal contact gradational 22

CUYAHOGA FORMATION, UNSUBDIVIDED

4. Interbedded fine-grained, thin-bedded sandstone and gray silty shales similar to sandstone and shale of unit 2; poorly exposed; very fine grained clastic rocks in the form of shales, clay lenses, and clay pebble conglomerates constitute about 50 per cent of the total thickness of the unit; basal contact gradational 22

BLACK HAND MEMBER

3. Sandstone, coarse, massive; same as unit 1; basal contact gradational 5.0

CUYAHOGA FORMATION, UNSUBDIVIDED

2. Sandstone, moderate yellowish brown (10 YR 5/4), fine-grained with occasional grains of medium-grained sand, thin-bedded, soft; abundant clay galls; exposed only in bed of stream; a shale bed 1 foot thick crops out 9 feet above the base of the unit; shale is medium light gray (N6), slightly silty, with thin intercalated layers of fine-grained sandstone; base of unit gradational 25

BLACK HAND MEMBER

1. Sandstone, dark yellowish orange (10 YR 6/6) to light brown (5 YR 5/6), locally dark reddish brown (10 R 3/4), poorly sorted, predominantly medium-grained, but grains range in size from silt to very coarse grained sand; grains subangular; pebbly; pebbles generally smaller than 1/4 inch but occasionally as large as 3/4 inch in diameter; pebbles commonly scattered, but in one instance occurring as a conglomeratic zone 2 inches in thickness; generally massive, but locally thin-bedded; in places thin-bedded portions seem to pass laterally into massive portions; clay galls of all sizes up to 4 inches in diameter scattered throughout unit; galls generally are subparallel to bedding, but on occasion are randomly oriented; galls locally concentrated into "clay pebble conglomerate" lenses as much as 1 foot in thickness; occasional clay lenses up to 3

	Feet
inches in thickness; irregular hydrous iron oxide bands up to 1/2 inch thick common; sandstone rather friable and soft; occurs in bed of stream and as occasional ledges along stream banks; similar, intermittent ledges may be traced south to Clear Creek.	35

Elevation at base of section 920 feet (Paulin altimeter)

O. G. S. 14598

Stratigraphic section of Mississippian strata in section 6, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured in the SE$\frac{1}{4}$ of the section in the west-flowing tributary of the Blue Valley which intersects the pumping station road approximately four-tenths of a mile northeast of the 1082-foot road corner, and along the road to the hilltop at the sharp bend in the road about half a mile northeast of the 1082-foot road corner.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
ALLENSVILLE MEMBER

4. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6); consists of very coarse grained sand in a matrix of very fine grained to fine-grained sand; thin- to medium-bedded; weathered feldspar common; heavily iron stained; poorly exposed; base not seen. 2.0

BYER MEMBER

3. Siltstone, grayish orange (10 YR 7/4), iron-stained on weathered surfaces, thin-bedded, soft, poorly exposed; base covered. 32

2. Covered interval. 24

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

1. Sandstone, light brown (5 YR 5/6) to moderate brown (5 YR 4/4), poorly sorted; grain size ranges from silt or clay to very coarse grained sand; medium-grained sand most abundant; grains subangular; scattered granules and pebbles and streaks of granules and pebbles along sweeps of cross beds; pebbles rarely exceed 1/4 inch in diameter; massive, friable; honeycomb weathered; shelter caves at base; apparent dips of beds range from 4°, N. 23° W. to 11°, N. 43° E.; base not seen. 48

Elevation at base of section 1009 feet (Paulin altimeter)

O. G. S. 14599

Stratigraphic section of Mississippian strata in section 11, Madison Township, Fairfield County, Lancaster quadrangle.

Measured on the steep eastern wall of the valley of Clear Creek directly east of the house located at the sharp bend in the road in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ of the section, and north along the more gentle slope, in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ of the section, which rises to the 1100-foot hilltop.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

5. Sandstone, dark yellowish orange (10 YR 6/6), irregularly iron stained, poorly sorted, fine-grained to very coarse grained with abundant silt and clay; medium-grained sand predominant; grains subangular; massive, ledge-forming, friable, honeycomb weathered; scattered clay galls generally near 1/4 inch in diameter; base not seen. 15

RACCOON MEMBER(?)

4. Covered interval; a few fragments of very light gray (N8), soft, slightly silty shale . . . 75

BLACK HAND MEMBER

3. Sandstone, grayish orange (10 YR 7/4); consists of fine-grained, subangular sand with a small amount of medium-grained sand; several pebbly zones, ranging in thickness from a few inches to a foot and grading upward into fine-grained sandstone, rise and fall across the face of the outcrop suggesting the filling of scoured surfaces; massive, fairly hard; irregular hydrous iron oxide bands up to 1/2 inch in thickness; shelter cave at base; base covered . . . 20

2. Covered interval. 50

1. Sandstone, grayish orange (10 YR 7/4) to light brown (5 YR 5/6), fine- to medium-grained with a small amount of coarse-grained sand; grains subangular; massive, forms a sheer cliff along the stream bank, hard; occasional irregular hydrous iron oxide bands up to 1/2 inch thick; shelter caves at base; base covered 50

Elevation at base of section 820 feet (estimated from topographic contours; thicknesses by aneroid barometer)

O. G. S. 14600

Stratigraphic section of Mississippian strata in section 24, Madison Township, Fairfield County, Lancaster quadrangle.

Section measured in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ of the section in the small steep ravine which empties into Clear Creek about three-tenths of a mile west of the 798-foot road corner.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

5. Sandstone, dark yellowish orange (10 YR 6/6), poorly sorted; consists of very fine grained to very coarse grained subangular sand and occasional granules; massive, friable, vaguely crossbedded; basal contact gradational. 12.5

4. Sandstone, moderate yellowish brown (10 YR 5/4), poorly sorted; consists of very fine grained to very coarse grained subangular sand and subrounded to rounded pebbles as large as 1/2 inch in diameter, but generally smaller than 1/4 inch in diameter; abundant randomly oriented clay galls up to 5 inches in diameter; massive; forms a prominent ledge along the top of the ravine; friable; occasional honeycomb weathering; base covered 20.0

3. Covered interval. 8.5

2. Sandstone, dark yellowish orange (10 YR 6/6), locally moderate reddish brown (10 R 4/6), fine- to medium-grained; grains subangular; varies from massive to thin-bedded; occasional "clay-pebble conglomerates" and thin clay layers; hydrous iron oxide bands up to 1/2 inch thick; friable; intermittently exposed on the floor of the ravine and in low ledges along the banks of the ravine 96

1. Sandstone, dark yellowish orange (10 YR 6/6), fine- to medium-grained; grains subangular; massive, friable, ledge-forming; small shelter cave at base of outcrop with a thin clay layer at base of shelter; clay is 1/4 inch thick, and is in sharp contact with the sandstones above and below; irregular hydrous iron oxide bands about 1/16 inch in thickness; a single "clay-pebble conglomerate" lens observed; lens is 2 feet wide and has a maximum thickness of 4 inches; clay galls in the lens range from 1/4 inch to 2 inches in diameter and are randomly oriented; base of unit covered 9.8

Elevation at base of section 813 feet (Paulin altimeter)

O. G. S. 14601

Stratigraphic section of Mississippian strata in section 16, Good Hope Township, Hocking County, Lancaster quadrangle.

Measured in the NE¼ of the section in the ravine which opens into the valley of Clear Creek just west of the line between sections 15 and 16.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BERNE AND BYER MEMBERS

10. In the roots of an overturned tree, fragments of grayish orange (10 YR 7/4) siltstone (Byer), conglomeratic sandstone (Berne?), and coarse-grained sandstone (Black Hand?).

9. Covered interval. 20

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

8. Sandstone, pale yellowish brown (10 YR 6/2); consists of medium-grained to very coarse grained sand with abundant granules and pebbles smaller than 1/4 inch in diameter and a small amount of interstitial silt or clay; massive, friable; base covered 11.0

7. Covered interval. 24

6. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6); varies from fine- to medium-grained sandstone to medium- to coarse-grained sandstone with occasional granules and local pebbly zones in which the pebbles are smaller than 1/4 inch in diameter; sand subangular; massive, ledge-forming; forms a shelter cave 100 to 150 feet in width across the ravine; honeycomb weathering on sheer walls outside of shelter; occasional irregular hydrous iron oxide bands generally about 1/4 inch in thickness; approximately 15 feet above the base of the unit, inaccessible on the overhanging lip of the shelter, is a large scour with a relief of several feet which can be traced for the entire width of the shelter; immediately overlying the scoured surface is a pebbly sandstone which grades upward quickly into the typical sandstone of the unit; maximum pebble diameter is 1/2 inch; base of unit sharp and slightly undulatory on unit 5 50

RACCOON MEMBER

5. Clay, very light gray (N8), sandy, soft, plastic; wedges out into the sandstones of units 4 and 6 at the southwest end of the shelter; basal contact sharp. 0-0.6

BLACK HAND MEMBER

4. Sandstone, dark yellowish orange (10 YR 6/6) to pale brown (5 YR 5/2); consists of subangular, medium- to coarse-grained sand, commonly with quartz overgrowths; massive, friable except where excessively ferruginous; in the southwestern portion of the shelter it passes into unit 6, from which it is indistinguishable; to the north (i.e. toward the rear center of the shelter) units 4 and 6 are separated by the clay of unit 5; base covered in the central and northeast portions of the shelter, but sharp and undulatory in the southwestern portion of the shelter with a relief of 4.5 feet in a horizontal distance of 45 feet; thickens where it passes into the base of unit 6 . . . . 3.3

RACCOON MEMBER

3. Mudstone, medium light gray (N6), silty, micaceous, soft; exposed in southwestern portion of shelter; base not seen. 2.0-6.5

2. Covered interval. 16.0

1. Interbedded siltstone and shale; individual beds range from 1 to 3 inches in thickness.

Feet

Siltstone, medium light gray (N6), micaceous, hard; scattered, paper-thin, argillaceous lenses about 1/2 inch in width oriented subparallel to the bedding.
Shale, medium dark gray (N4), silty, slightly micaceous, soft, iron-stained on bedding surfaces.

Base of unit covered. 8.0

Elevation at base of section 868 feet (Paulin altimeter)

O. G. S. 14602

Stratigraphic section of Mississippian strata in sections 8 and 9, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured in the NW$\frac{1}{4}$ of section 9 and the NE$\frac{1}{4}$ NE$\frac{1}{4}$ of section 8 in the ravine which opens into the valley of Brushy Fork about four-tenths of a mile east of the 825-foot road corner.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
BERNE AND BYER MEMBERS

14. In the roots of an overturned tree just above the top of unit 13 are fragments of coarse-grained, ferruginous sandstone with heavy hydrous iron oxide bands (Berne) and dark yellowish orange (10 YR 6/6) siltstone (Byer).

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

13. Sandstone, grayish orange (10 YR 7/4) to moderate reddish brown (10 R 4/6); generally fine- to medium-grained with abundant silt or clay; locally coarser with scattered granules and pebbles usually smaller than 1/8 inch in diameter; pebbles as large as 3/4 inch in diameter in the pebbly zone overlying a scour; massive, hard; forms a large shelter at the head of the ravine; ferruginous nodules and tubes, generally not over 1 inch in diameter, common; beds dip 16°, N. 60° E. with small, local crossbeds within the dipping beds showing apparent dips to the northwest; near the base of the shelter the westernmost dipping beds pass downward into horizontal beds; to the east the dipping beds are truncated by the horizontal beds; which, in turn, are truncated eastward by dipping beds; base of unit covered. 35

12. Covered interval. 56

11. Sandstone, light olive gray (5 Y 6/1) to grayish orange (10 YR 7/4); consists of subangular, medium- to coarse-grained sand with occasional pebbly zones containing pebbles generally smaller than 1/8 inch in diameter; massive, friable, ledge-forming; base covered. 50

10. Covered interval. 10.0

Feet

RACCOON MEMBER

9. Shale, same as in unit 7; not intercalated sandstone. 2.2

8. Covered interval 20.0

7. Shale, medium light gray (N6), silty, micaceous, soft, intermittently exposed; with thin intercalated sandstones occurring in beds about 1 inch thick; sandstone is medium light gray (N6), very fine grained, micaceous, hard, contains scattered carbonaceous fragments, and is in sharp contact above and below with the shale; base of unit covered 5.0

6. Covered interval 14.0

BLACK HAND MEMBER

5. Sandstone, dark yellowish orange (10 YR 6/6), fine- to coarse-grained, but predominantly medium-grained; grains subangular, massive, friable; weathers thin-bedded; intermittently exposed in stream bed; base not seen 4.0

4. Covered interval. 2.4

3. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4); consists mainly of subangular medium-grained sand; varies locally to very coarse grained sandstone with granules and occasional pebbles smaller than 1/8 inch in diameter; massive; forms a low shelter in the stream bed; base covered. 4.0

2. Covered interval 18.0

1. Sandstone, moderate yellowish brown (10 YR 5/4); consists of subangular, medium- to coarse-grained sand with scattered subrounded granules and grains of very coarse grained sand coated with hydrous iron oxide; massive, ledge-forming, somewhat friable; occasional hydrous iron oxide bands as thick as 1/4 inch; base covered. 23.0

Elevation at base of section 805 feet (Paulin altimeter)

O. G. S. 14603

Stratigraphic section of Mississippian strata in section 4, Berne Township (T. 13 N.), Fairfield County, Lancaster quadrangle.

Measured in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ of the section in the second ravine north of the line between sections 4 and 9.

Feet

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
ALLENSVILLE MEMBER

6. Sandstone, dark yellowish orange (10 YR 6/6); consists of very coarse grained, sub-

	Feet
angular sand with overgrowths in a matrix of very fine grained ferruginous sand; scattered grains of weathered feldspar; rather friable; occurs as a few loose fragments at the crest of the ridge.	

BYER MEMBER

	Feet
5. Sandstone, dark yellowish orange (10 YR 6/6), very fine grained, slightly micaceous, thin- to medium-bedded; not exposed; occurs as abundant float to the top of the north valley wall; base not seen; no evidence of the Berne member.	47

Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

	Feet
4. Sandstone, light olive gray (5 Y 5/2) to moderate brown (5 YR 3/4); varies from fine- to medium-grained sandstone to a poorly sorted sandstone containing grains of all sizes up to 1/2 inch; pebbles usually smaller than 1/8 inch in diameter; crossbedded, with the coarser sandstone in the crossbedded portions; pebbles especially abundant along the sweeps of the cross beds, which dip in all directions; massive, somewhat friable, cliff-forming; local honeycomb weathering; dip of beds variable, but to the northeast; largest apparent dip measured 13°, N. 45° E., on south wall of ravine; the uppermost beds are horizontal; base covered.	88
3. Covered interval.	25
2. Sandstone, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4), iron-stained, fine- to medium-grained; grains subangular; massive, friable, poor ledge-former; basal contact sharp.	7.5

RACCOON MEMBER

	Feet
1. Sandstone and shale interbedded. Shale, light gray (N7), silty, micaceous, soft; thickness ranges from about 1 inch near the top of the unit to 1 foot or more near the base of the unit; shale-sandstone contacts sharp. Sandstone, medium light gray (N6), occasionally iron-stained, very fine grained to fine-grained, hard; forms small ledges in stream bank and low waterfalls in bed of stream; some layers contain thumbnail-sized argillaceous lenses; flow casts common; thickness of layers ranges from 1/2 to 12 inches with the beds thinner and more widely spaced near the base of the unit and becoming thicker and more closely spaced in the upper portion. Unit intermittently exposed; base not seen.	51

Elevation at base of section 817 feet (Paulin altimeter)

O. G. S. 14604

Stratigraphic section of Mississippian strata in section 32, Berne Township, Fairfield County, Lancaster quadrangle.

Measured in the NW$\frac{1}{4}$ of the section on Blue Valley road just east of Blue Valley school and along the lane running northwest from Blue Valley School.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

	Feet
5. Sandstone, dark yellowish orange (10 YR 6/6) to moderate brown (5 YR 3/4), irregularly iron stained, poorly sorted; consists of very fine grained to very coarse grained subangular sand with abundant, scattered, subangular to subrounded granules and pebbles as large as 1/4 inch; massive, friable; local hydrous iron oxide concentrations form nodes on weathered surface; base not seen. .	65
4. Covered interval.	29

CUYAHOGA FORMATION, UNSUBDIVIDED

	Feet
3. Sandstone, moderate yellowish brown (10 YR 5/4), irregularly iron-stained, mottled black on weathered surface, very fine grained to fine-grained, thin-bedded, hard; occurs as abundant fragments in the bank beside the lane. Sparse fragments of shale, pale yellowish brown (10 YR 6/2), silty, micaceous, soft. Thickness based on float.	23
2. Covered interval	83

BLACK HAND MEMBER

	Feet
1. Sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), fine- to coarse-grained with scattered grains of very coarse grained sand; grains subangular; massive except for the lowermost 1 foot, which is thin to medium bedded; friable; quartz overgrowths common; base covered	12

Elevation at base of section 800 feet (Paulin altimeter)

O. G. S. 14605

Stratigraphic section of Mississippian strata in section 13, Madison Township, Fairfield County, Lancaster quadrangle.

Section measured in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ of the section on the north side of the Clear Creek road approximately 300 feet east of the 796-foot road corner.

Feet

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
BLACK HAND MEMBER

	Feet
4. Sandstone, light brown (5 YR 5/6), poorly sorted; grain size ranges from very fine grained to coarse grained; sandstone is predominantly fine to medium grained; small amount of interstitial silt or clay; massive, hard, ledge-forming; occasional honeycomb weathering; occasional hydrous iron oxide bands with a maximum thickness of 1/4 inch; shelter caves at base; base not seen. . .	44.0
3. Covered interval.	4.2

	Feet
2. Sandstone, dark yellowish orange (10 YR 6/6), fine- to medium-grained; grains subangular; thin- to medium-bedded; thin irregular hydrous iron oxide bands up to 1/16 inch in thickness; scattered clay galls up to 1 inch in diameter; base not seen.	6.6
1. Sandstone, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4), fine- to medium-grained with abundant interstitial silt or clay; grains subangular; slightly micaceous; massive, hard; forms a prominent ledge along the north side of the road; base not seen.	11.0

Elevation at base of section 796 feet (hand level)

	Feet
3. Mudstone, light olive gray (5 Y 5/2), very slightly silty, blocky, slightly micaceous, poorly exposed; base covered.	0.3
2. Covered interval.	5.0

DEVONIAN SYSTEM
Ohio shale

1. Shale, black (N1), very slightly silty, fissile; small exposure in stream bed; float continues downstream; base not seen; thickness not measured.

Elevation at top of Ohio shale 776 feet (Paulin altimeter)

O. G. S. 14606

Stratigraphic section of Mississippian strata in section 6, Bloom Township, Fairfield County, East Columbus quadrangle.

Measured along tributary of Walnut Creek which flows through the eastern and northern portions of the section.

MISSISSIPPIAN SYSTEM
Kinderhook and Osage Series
Cuyahoga formation
RACCOON MEMBER

	Feet
10. Siltstone to very fine grained sandstone and mudstone interbedded. Siltstone to very fine grained sandstone, yellowish gray (5 Y 7/2) to moderate yellowish brown(10 YR 5/4), thin-bedded, hard, slightly micaceous; abundant oval cavities up to 2 inches in diameter on some bedding surfaces; cavities resemble those from which clay galls have been removed by weathering. Mudstone, medium gray (N5), slightly iron stained, soft, slightly micaceous; abundant carbonaceous fragments. Exposure slumped; base not seen	12.0
9. Covered interval	10.0

Kinderhook Series
Sunbury shale

	Feet
8. Shale, black (N1), fissile, hard, brittle; sandy in basal 1 inch; basal contact sharp . . .	13.5

Berea sandstone

	Feet
7. Sandstone, olive gray (5 Y 4/1), heavily iron stained on weathered surfaces, very fine grained, massive, hard; oscillation ripple marks with crests trending S. 70° E.; base not seen	4.2
6. Covered interval	5.0

Bedford shale

	Feet
5. Mudstone, grayish red (10 R 4/2), iron-stained, very slightly silty, blocky, slightly micaceous; occasional thin marcasitic or pyritic siltstone ledges; base covered.	45
4. Covered interval	7.0

O. G. S. 14607

Stratigraphic section of Mississippian strata in section 33, Richland Township, Fairfield County, Thornville quadrangle.

Measured in the NW¼ NW¼ NW¼ of the section on the east bank of Rush Creek.

MISSISSIPPIAN SYSTEM
Osage Series
Logan formation
VINTON MEMBER

	Feet
9. Sandstone, pale yellowish brown (10 YR 6/2) to moderate brown (5 YR 4/4), very fine grained, thin- to medium-bedded, hard, micaceous; brachiopods and crinoid columnals abundant in restricted beds; occasional thin (1 to 6 inches) intercalations of sandstone, light olive gray (5 Y 5/2), very fine grained, very thin bedded, laminated, soft; basal contact of unit sharp.	9.5
8. Mudstone and siltstone with occasional thin layers of fine-grained sandstone, medium dark gray (N4) to yellowish gray (5 Y 7/2), iron-stained, thin-bedded; fine lamination particularly well developed in sandstone layers; basal contact sharp.	31.0

ALLENSVILLE MEMBER

	Feet
7. Sandstone, medium light gray (N6) to moderate yellowish brown (10 YR 5/4) to brownish black (5 YR 2/1); irregular heavy iron staining; medium- to coarse-grained, argillaceous, massive, with some poorly formed thin bedding, friable; basal contact sharp.	2.8
6. Sandstone, grayish orange (10 YR 7/4), iron-stained, very fine grained, thin- to medium bedded; poorly formed lamination; hard; near top are 1/2-inch nodules of coarse-grained sandstone as in unit 7; basal contact sharp	2.3
5. Sandstone, moderate yellowish brown (10 YR 5/4), iron-stained, medium- to coarse-grained; occasional silty layers up to 3 inches thick; massive, slightly friable; basal contact gradational.	5.0
4. Sandstone, mottled dark gray (N3) and light gray (N7), weathers to pale olive (10 Y 6/2),	

	Feet
very fine grained, massive; poorly developed thin bedding in part; characterized by spalling on vertical stream-cut cliff; hard, micaceous; numerous small lens-shaped cavities on weathered surface; basal contact gradational.	9.6
3. Siltstone, medium light gray (N6), slightly iron stained, poorly developed thin bedding, micaceous, somewhat soft; scattered pelecypods; basal contact gradational.	6.3
2. Sandstone, light olive gray (5 Y 6/1), lightly and irregularly iron stained, medium- to coarse-grained, thin-bedded; bedding poorly developed; slightly friable; basal contact sharp	0.6
BYER MEMBER	
1. Sandstone, medium gray (N5) to moderate olive brown (5 Y 4/4), very fine grained, thin- to medium-bedded, hard, slightly micaceous, ripple marked; base not exposed	1.0

Elevation at base of section 845 feet (aneroid barometer)

O. G. S. 14608

Stratigraphic section of Mississippian strata in section 28, Richland Township, Fairfield County, Thornville quadrangle.

Measured in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ of the section on the east bank of Rush Creek just north of the new highway bridge and in road cuts along the highway just east of the new bridge.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
VINTON MEMBER	
16. Alternating sandstone, siltstone, and mudstone similar to those below; poorly exposed. .	16.0
15. Siltstone to fine-grained sandstone, light olive gray (5 Y 5/2), bedding ranges from thin bedded to massive (1/4 inch to 2 feet), finely laminated, micaceous, hard; basal contact gradational.	7.2
14. Mudstone, medium dark gray (N4), some iron stains, silty, blocky, soft, micaceous; basal contact sharp	5.0
13. Sandstone, dark yellowish brown (10 YR 4/2), iron-stained, very fine grained, massive, finely laminated in part, hard, sparingly fossiliferous (brachiopods and crinoid columnals); basal contact sharp	12.0
12. Mudstone, light olive gray (5 Y 6/1) to dark yellowish brown (10 YR 4/2), silty, very thin bedded, micaceous, soft; base covered . . .	1.3
11. Covered interval	11.5
10. Sandstone, dark yellowish brown (10 YR 4/2), iron-stained, fine-grained, very thin bedded, soft, argillaceous; base covered. . .	4.7
9. Covered interval.	2.4
8. Siltstone to very fine grained sandstone, light olive gray (5 Y 5/2) to moderate yellowish brown (10 YR 5/4), iron-stained, thin- to medium-bedded, finely laminated, hard; occasional thin shale intercalations in upper 3 feet; very fossiliferous with abundant brachiopods, crinoid columnals and occasional pectinids; base covered.	9.3
7. Covered interval.	12.2
6. Siltstone to silty mudstone, yellowish gray (5 Y 7/2), iron-stained, thin-bedded, soft, micaceous; occasional layers of concretions; basal contact sharp	17.5
ALLENSVILLE MEMBER	
5. Sandstone, light gray (N7) to moderate brown (5 YR 4/4), heavily iron stained, medium- to coarse-grained, massive, somewhat friable; basal contact sharp	4.2
4. Sandstone, light gray (N7) to pale red (5 R 6/2) to light brown (5 YR 5/6), iron-stained, fine-grained, thin-bedded, laminated in part, hard; basal contact sharp	1.3
3. Mudstone, dark yellowish brown (10 YR 4/2), silty, very thin bedded, soft; basal contact sharp	0.3
2. Sandstone, light olive gray (5 Y 5/2) to moderate yellowish brown (10 YR 5/4), medium-grained, massive, slightly friable, micaceous; basal contact sharp.	3.1
1. Sandstone, medium light gray (N6) to light olive gray (5 Y 6/1) with brownish gray (5 YR 4/1) streaks and mottling, some iron staining; fine-grained, massive, micaceous; occasional intercalations 1 to 6 inches thick of thin-bedded, silty mudstone; base covered.	9.1

Elevation at base of section 860 feet (aneroid barometer)

O. G. S. 14609

Stratigraphic section of Mississippian strata in section 26, Berne Township, Fairfield County, Lancaster quadrangle.

Measured along the pipeline in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ of the section from a point located half a mile south of the 819-foot road corner, where the pipeline intersects the road, to the first hilltop to the northeast.

	Feet
MISSISSIPPIAN SYSTEM	
Osage Series	
Logan formation	
ALLENSVILLE MEMBER	
4. Covered; abundant Allensville debris to hilltop.	

	Feet
BYER MEMBER	
3. Sandstone, moderate yellowish brown (10 YR 5/4) to light olive brown (5 Y 5/6), iron-stained, very fine grained, thin- to medium-bedded, soft	31.0
BERNE MEMBER	
2. Sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 5/4), medium- to coarse-grained, with granules in upper 3 feet; grains generally subrounded, with occasional quartz overgrowths; thin-bedded, becoming massive in upper 3 feet, friable; irregular hydrous iron-oxide bands; largely covered, description generalized.	10.0
Kinderhook and Osage Series	
Cuyahoga formation	
BLACK HAND MEMBER	
1. Sandstone, moderate reddish brown (10 R 4/6) to dark yellowish orange (10 YR 6/6), well-sorted; consists of subrounded coarse-grained sand and occasional grains of very coarse grained sand and granules; massive, friable.	6.0

Elevation at base of section 852 feet (aneroid barometer)

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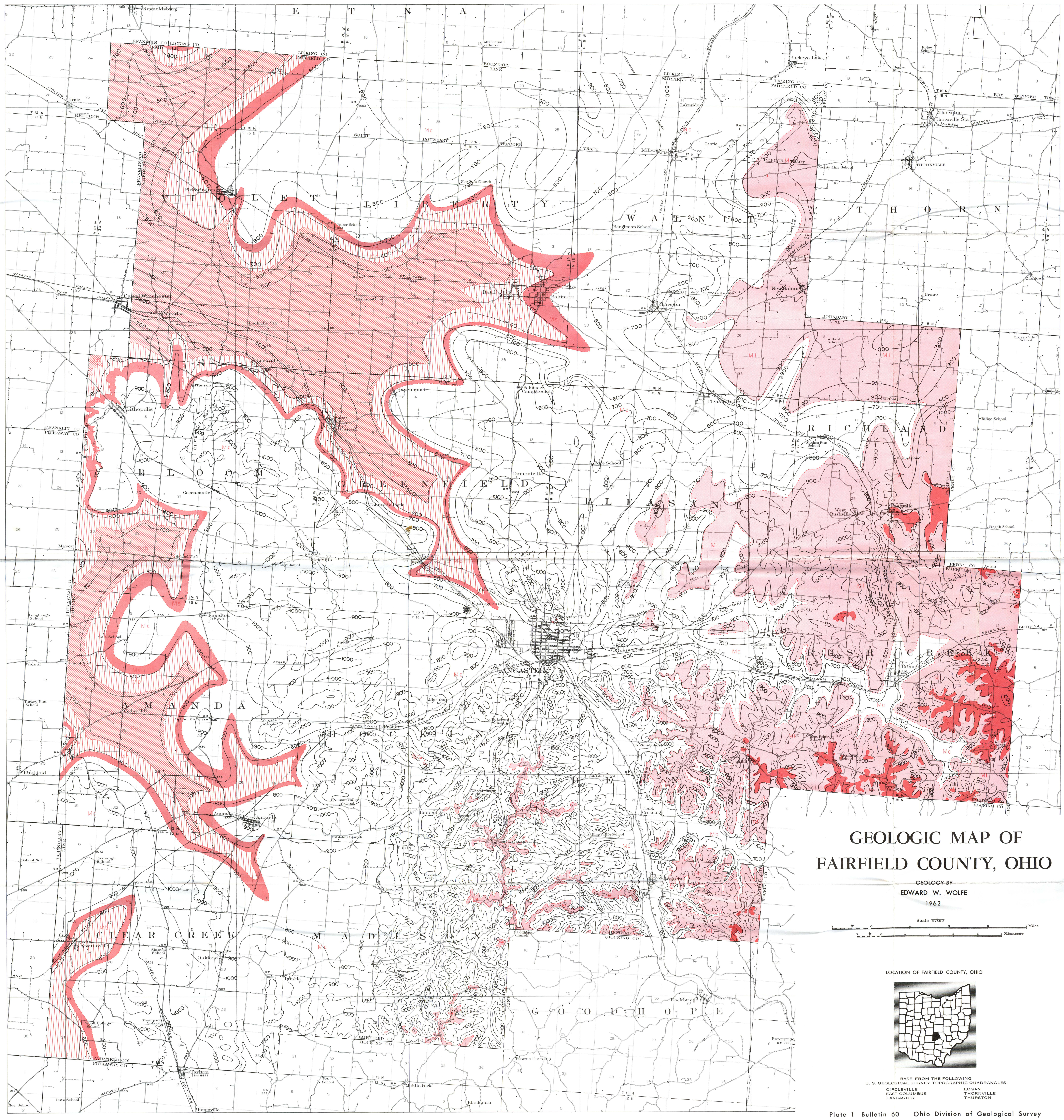

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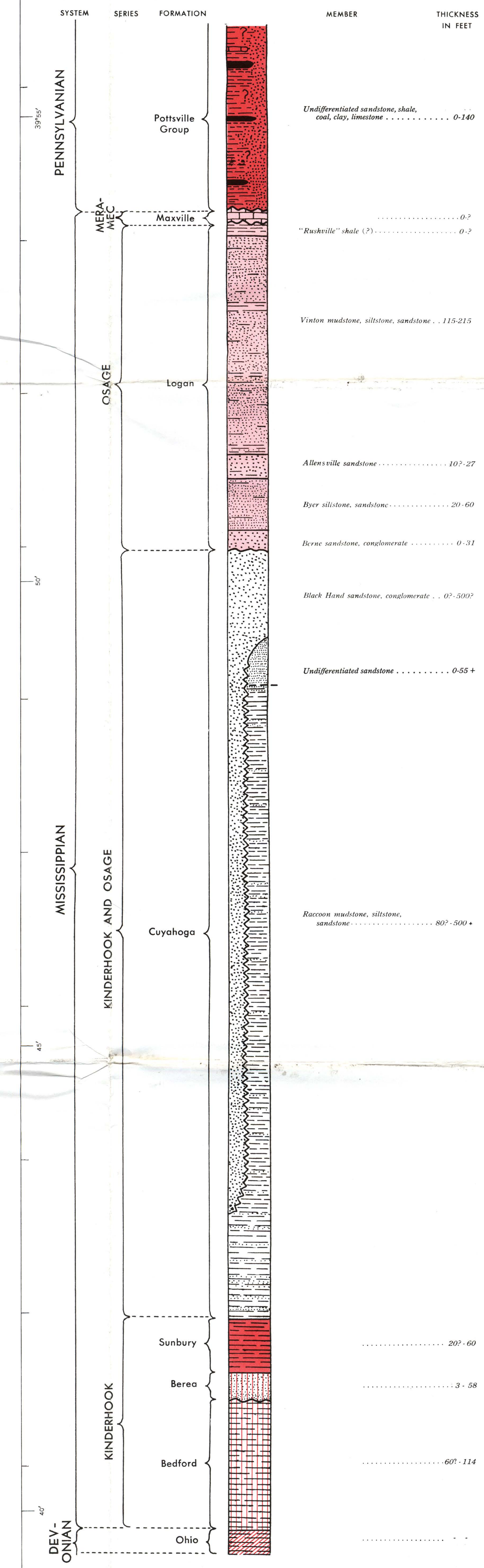


EXPLANATION

PENNSYLVANIAN SYSTEM

Pp — Pottsville group

MISSISSIPPIAN SYSTEM

Ml — Logan formation

Mc — Cuyahoga formation

Ms — Sunbury shale

Mb — Berea sandstone and Bedford shale, undifferentiated

DEVONIAN SYSTEM

Doh — Ohio shale

SYMBOLS

——— Geologic contact, intermittently exposed

- - - - - Geologic contact, inferred

—700— Contours on bedrock surface (contour interval 100 feet)

GEOLOGIC MAP OF FAIRFIELD COUNTY, OHIO

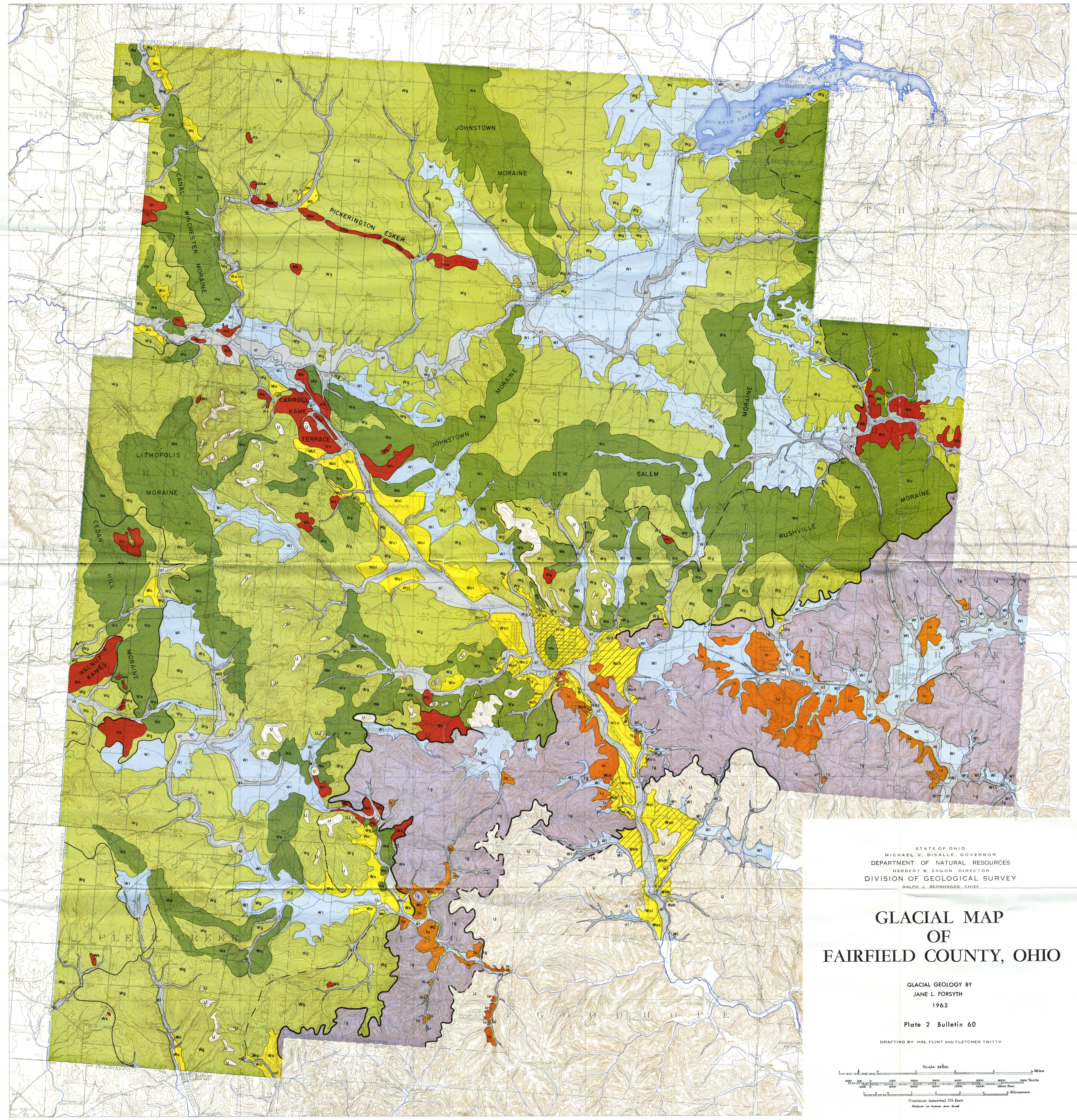
GEOLOGY BY
EDWARD W. WOLFE
1962

Scale 1/62500

LOCATION OF FAIRFIELD COUNTY, OHIO

BASE FROM THE FOLLOWING
U. S. GEOLOGICAL SURVEY TOPOGRAPHIC QUADRANGLES:
CIRCLEVILLE, EAST COLUMBUS, LANCASTER, LOGAN, THORNVILLE, THURSTON

DRAFTING BY FLETCHER W. TWITTY



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GLACIAL MAP OF FAIRFIELD COUNTY, OHIO

GLACIAL GEOLOGY BY
JANE L. FORSYTH
1962

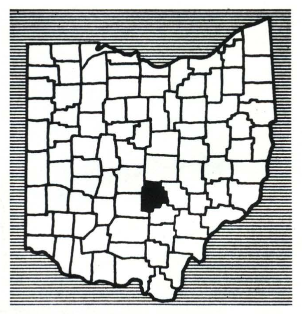
Plate 2 Bulletin 60

DRAFTING BY HAL FLINT AND FLETCHER TWITTY

Scale $\frac{1}{62500}$

Contour interval 20 feet
Datum is mean sea level

LOCATION OF FAIRFIELD COUNTY, OHIO



BASE COMPILED
FROM THE FOLLOWING U. S. GEOLOGICAL SURVEY
TOPOGRAPHIC MAPS

EAST COLUMBUS	CIRCLEVILLE
THURSTON	LOGAN
THORNVILLE	LANCASTER

EXPLANATION

RECENT

al — Stream alluvium

PLEISTOCENE

WISCONSIN

Wl — Lake silts

Woh, Wol, Woc, Wo — Outwash terraces:
Woh - high level constructional terrace
Wol - low level constructional terrace
Woc - low level "cut" terrace
Wo - Undifferentiated terrace
diagonal lines identify terraces capped by silt

Wk-Wke — Kames (Wk) and eskers (Wke)

We — End moraines

Wg — Ground moraine

ILLINOIAN

Io — Outwash terraces

Ig — Ground moraine

SYMBOLS

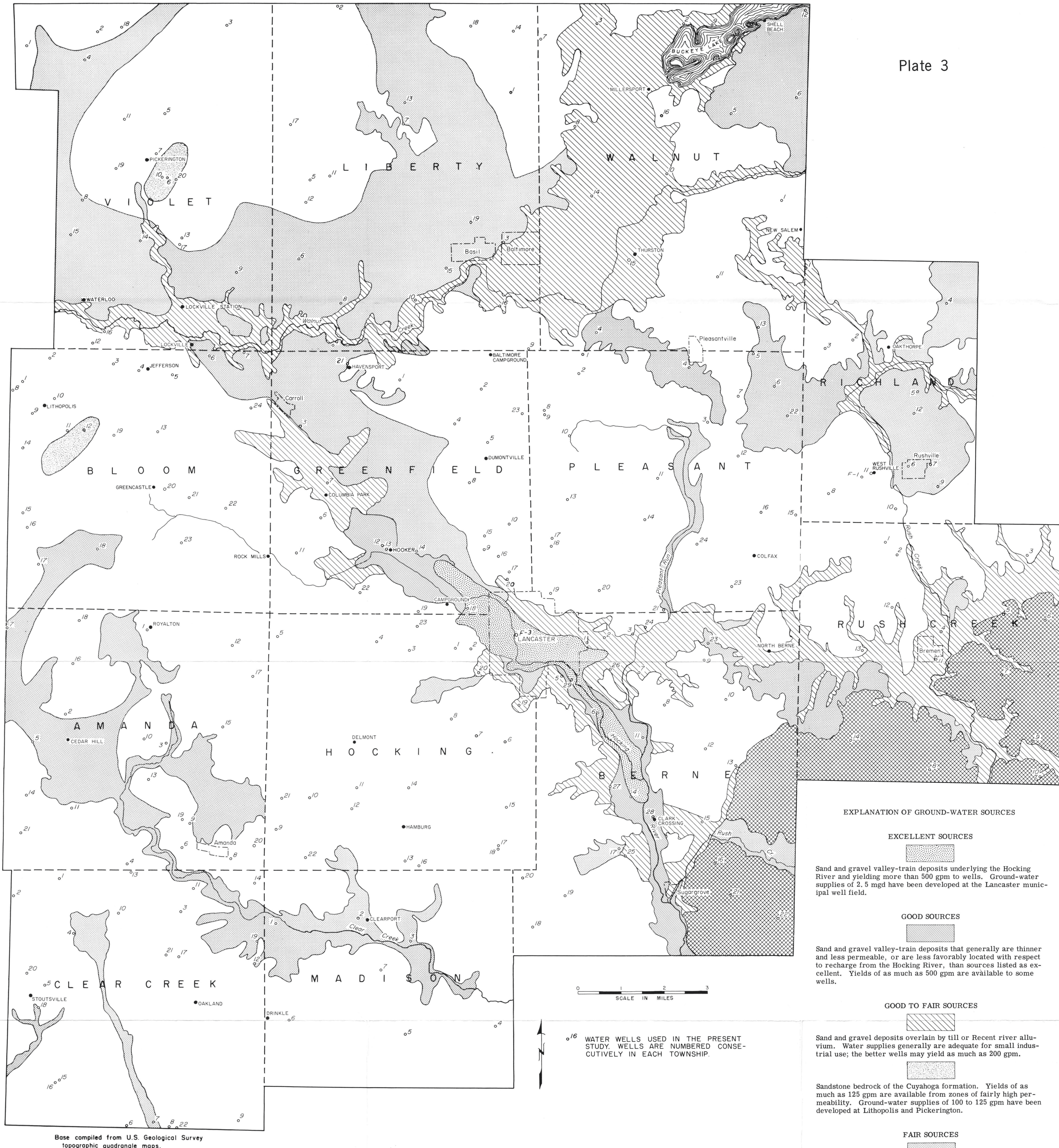
U — Unglaciated areas south of glacial boundary or drift-free areas of bedrock north of glacial boundary

Crestlines

Lines marking boundaries of Wisconsin and Illinoian drifts

Lines marking boundaries of different soil catenas within the area of Wisconsin till

Plate 3



Base compiled from U.S. Geological Survey topographic quadrangle maps.

Bedrock geology after E.W. Wolfe and glacial geology after J.L. Forsyth.

Drafting by Diana Pfannebecker

MAP SHOWING
THE GROUND-WATER RESOURCES OF
FAIRFIELD COUNTY, OHIO
BY GEORGE D. DOVE

Plate 3 Bulletin 60 Ohio Division of Geological Survey

EXPLANATION OF GROUND-WATER SOURCES

EXCELLENT SOURCES

Sand and gravel valley-train deposits underlying the Hocking River and yielding more than 500 gpm to wells. Ground-water supplies of 2.5 mgd have been developed at the Lancaster municipal well field.

GOOD SOURCES

Sand and gravel valley-train deposits that generally are thinner and less permeable, or are less favorably located with respect to recharge from the Hocking River, than sources listed as excellent. Yields of as much as 500 gpm are available to some wells.

GOOD TO FAIR SOURCES

Sand and gravel deposits overlain by till or Recent river alluvium. Water supplies generally are adequate for small industrial use; the better wells may yield as much as 200 gpm.

Sandstone bedrock of the Cuyahoga formation. Yields of as much as 125 gpm are available from zones of fairly high permeability. Ground-water supplies of 100 to 125 gpm have been developed at Lithopolis and Pickerington.

FAIR SOURCES

Sand and gravel deposits of small areal extent, interbedded in till. Ground-water supplies generally are adequate for domestic or stock use.

Sandstone and siltstone bedrock of Mississippian age. Yields of 5 to 50 gpm are available to some wells. Ground-water supplies for home or farm use generally are available from wells drilled into the top few feet of these rocks.

POOR SOURCES

Siltstone of the Logan formation. Yields of less than 3 gpm are available to wells. Domestic and farm supplies may be developed from deeper wells drilled into the underlying Cuyahoga formation.